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Under Maintenance

- An Analysis of Rent Control and its Effects on Property Maintenance

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Abstract. In this paper, I analyse the impact of rent control on property maintenance, with the purpose of furthering understanding of the rent control phenomenon and contributing to the academic debate. Most economic schools would agree that rent controls, de facto being price ceilings of some form, lessen the incentives for landlords to maintain their properties, as the costs cannot be recouped through higher rent levels. I analyse this claim by looking at the landlord's problem through an optimal control lens, drawing heavily on a model developed by Arnott, Davidson and Pines in 1983. The qualitative result is that under vacancy decontrol rent control systems, landlords have strong incentives to postpone maintenance until the tenancy's final periods as to increase the quality for the subsequent tenant who can be charged a higher rate. This modelling result is contrasted with panel data from Canadian provinces, where there is variation in rent control within and between provinces over time. While the quantitative results are less than convincing, the qualitative implications are in line with the model, par the seemingly deterministic increase in maintenance expenditures over time. My conclusion is that even though the model is comprehensive and intuitively formulated, it is unfit to use when looking at an extended period of time as it assumes static parameters.

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1 Introduction

The question of, and subsequent academic scrutiny of, rent control is by no means something new. Since the large-scale implementations of rent freezes and similar measures during the second world war, economists have considered many approaches to the issue. While analysis of the so-called first generation rent control schemes, acting as de facto price ceilings, are overwhelmingly negative, rent control schemes have evolved a lot since the 1940s. Today's models of course differ depending on which legislative jurisdiction is analysed, but are in general more focused on limiting price increases as opposed to the base price. There is also a large trend of allowing conditional exceptions to the rent control rules, e.g. when constructing new buildings or investing in renovations. While the classical viewpoint of non-interventionism still is vocal, there are a number of studies suggesting that well-designed rent control schemes of the second generation can actually improve welfare, and should as such be analysed in a new light as opposed to being bunched together with the price ceiling models of the past.

Why then is rent control such a studied topic? The answer is in short that housing is incredibly important. Since rent control affects the housing outcomes for a large number of households worldwide, and housing affects the economy to a large extent, rent control systems affect entire economies and are as such important to fully understand. The causal effects of housing on economic outcomes are many, but a notable point is that for a lot of households, housing is the number one expense in the month-to-month budget. Thus, a household might be very sensitive to changes in housing costs: a ten percent increase in rent might force a household to move, as opposed to a ten percent increase in the price of milk which barely would be noticeable. Furthermore, housing and vacancy rates play a significant role in the labour market, specifically when it comes to labour mobility. A firm in e.g. San Francisco might have trouble attracting workers due to unaffordable and/or nonexistent housing locally. It then goes that a sound, well-designed rent policy (or absence of one) could in fact improve labour mobility and reduce systematic unemployment, thus boosting the economy. Finally, the importance of housing stretches beyond the scope of economics, to the degree that it is recognized by the U.N. as a fundamental human right. If it is the case that every human has a right to adequate housing, it must be the case that society as a whole has an obligation to provide said housing. Whether rent control is a tool or an obstacle in that quest is further motivation as to why it's an important issue.

As the topic is broad, this paper will focus on a more narrow aspect of rent control, namely its possible adverse effect on property maintenance. Intuitively, a landlord who isn't able to charge as high a rent as they would like to would have less incentives to maintain the property. This would in turn mean that buildings ceteris paribus depreciate to a larger degree in geographical jurisdictions under rent control regimes than they would under a free market. As such, there are likely welfare losses associated with the low level of maintenance, inflicted on

both sides of the market. For a tenant, the quality of living might deteriorate as the landlord fails to properly maintain the building. Similarly, a building that's not well maintained ought to lose its value at a higher rate, thus damaging the owner of the property. In order to investigate this phenomenon, this paper utilizes a theoretical model developed by Arnott, Davidson and Pines (1983), characterizing the maintenance choices the landlord makes as an optimal control problem. A thorough model, functional forms and parameters are however arbitrarily decided and I make some alterations as to how these are defined. The goal is then to compare the results from the model to real-life panel data from Canada. The Canadian rent system is such that it is up to each province to decide for themselves what rent regimes, if any, should be enforced by the government. As such, there is variation between provinces at a given time, as well as variation within a province over time as the political landscape changes. The final goal is thus then to quantify, to as detailed an extent as possible, the adverse effects of rent control on maintenance, if any.

The structure of the paper is as following: I start by providing some context as to the political and historical context through which the debate surrounding rent control must be seen. I then provide an overarching literature review regarding rent control, the positions of economists and its effect on maintenance. The Arnott-Davidson-Pines model is then presented in full, solving the optimal control problem and showing what maintenance paths are profit-maximizing for the landlord given free market and rent control environment. I further present data and econometric output in the Canadian context and relate it to the presented model. I conclude with a discussion regarding policy implications, my own shortcomings and the limitations of the approach chosen.

2 Background

Rent control is the act of price intervention on the leasing market by a governmental body, often with the expressed goal of protecting tenants from predatory and arbitrary price fluctuations. As such, while rent control has become the status quo in a number of jurisdictions, the emergence of a majority of rent control systems has historically been connected with crises. World wars, recessions and most recently, the covid-19 pandemic, have all been cited as reasons for legislators to intervene on the free market. This is by no means unique for rent control: a number of economic and non-economic innovations have been introduced in times of crisis only to lose their temporary status once the crises have been averted. Comparable is e.g. inclusion of women in the workforce or nationalization of industries, introduced in many countries as war measures only to become commonplace.

The debate over whether or not rent control of any kind is desirable needs to be seen through the lens of political economy. Tenants do, always have, and probably always will, outnumber landlords. As such, they constitute a larger

voter group and will be favoured by any vote-maximizing political party in a democracy. This phenomenon is indisputable, but that does not automatically imply that rent control is bad. It has however been the traditional view by economists and capital owners alike that rent control constitutes a populist measure in that is creates a welfare loss at the gain of the popular vote of tenants. There is no debate whatsoever with regards to whether or not rent control is favourable for tenants with rent controlled contracts: in all its forms, it acts as a de facto subsidy, letting tenants lease at a lower rent than they would have without intervention. While this of course implies a lower producer surplus, the common arguments from the supply sides have been aimed at the tenants' welfare, in that it has focused mainly on the undersupply of leasable apartments brought upon the economy by rent control. Indeed, a majority of economic schools would agree to the fact that a price ceiling, whether or not it is enforced on nominal rents or increases, lowers the willingness of producers to supply properties to the market. It is therefore natural to question rent control in situations where vacancy rates are low but the demand for housing is high, as seen in e.g. New York or Stockholm.

It is however the case that from a political-ideological viewpoint might assign different values on the consumer and producer surpluses. Since the tenants living in rental contracts tend to be on the lower part of the income spectrum, rent control constitutes a de facto redistribution measure, transferring surplus from producers to consumers, albeit creating a deadweight loss. It might very well be the case that we as a society, not only through vote maximization, care more about the worse off than we do about landlords. This however needs to be contrasted with the undersupply of housing, which hurts producers and consumers alike. A common argument in this discussion is that given that we actually want to redistribute funds to tenants, rent control is an inefficient measure in doing so, as opposed to lump-sum transfers or tax credits. This inefficiency stems from both classic deadweight losses, but also the imprecise nature of the subsidy. It is not only the worse off who live in rental units, but the well off as well, and as such a directed transfer based on income would more precisely reach the target group. For instance, a 2017 governmental study found that the subsidies in Stockholm were the largest in absolute numbers for the inner city apartments, who by and large were inhabited by individuals higher up on the income spectrum, as they were the ones who could afford waiting in the queue for a long time (Donner et al., 2017).

Furthermore, rent control has the characteristic that it worsens the performance of the price mechanism to maximize welfare in a market. It is under rent control no longer the case that the consumers with the largest willingness to pay who consume the lowered supply, but instead the rentals are allotted through queue mechanisms, de facto lotteries with regards to the consumers' willingness to pay. This implies that a price ceiling, as drawn through in a neoclassical partial equilibrium analysis, in fact overstates the positive effects on consumer surplus. That being said, no serious economist currently characterizes rent con-

trol through triangles in a price-quantity chart. Rent control in its modern form is often more complicated than that, and combined with the general equilibrium effects housing has, the partial equilibrium analysis is far too unsophisticated to be of any use in policy recommendations.

Expanding on the political side, it is also plausibly the case in public discourse that the issue of rent control has become a proxy debate for belief in the free market. While it does go in line with left-right-political standpoints for the left to like governmental interventions more than the right, which has been the case with rent control, it is fair to assume that much of the debate is not about rent control per se, but of broader ideological preferences. Whether or not this has translated into the academic discourse is another question, but even given a sound academic discussion, it is the public debate that has larger policy implications. This is of course not unique for rent control, but is an important point to keep in mind when analysing public debate. There could furthermore even be non-economic, soft values involved in the debate of rent control. In the Swedish case, I would argue that the current model of a tenant's organization centrally negotiating rent increases with landlords has not solely remained for economic reasons, but even for cultural ones. There is a sense of cultural pride regarding what is known as "the Swedish model" of negotiating, creating additional inertia in the political system. Even if the Canadian provinces do switch back and forth and as such might not have as strong cultural attachments to rent control, I expect that some form of non-economic inertia will be present, either for or against rent control.

I finally want to make it clear that I by no means aim to conclude that rent control is either bad or good. As I will focus on a particular, narrow aspect of rent control, it would not make any sense for the results to validate positions regarding the entire concept. That being said, improving the understanding of all aspects of rent control should enhance mine as well as the reader's ability to form a factual argument regarding the system's merits and disadvantages. As such, while knowledge about rent control's effects on property maintenance are insufficient for assuming a position in the debate, they are a part of the puzzle.

3 Literature review

Housing economics is of course its own subdiscipline, and as such there is a plethora of literature on property matters. This literature review section will present research relating to both the narrow field of property maintenance and rent control as a whole, trying to relate the latter to maintenance when possible. While I by no means claim to cover all views represented in the economic discipline, I aim to provide an overview of positions in order to contextualize the rest of the paper.

3.1 Rent control

A famous paper with regards to creating an overview of economic opinions is Alson, Kearl & Vaughan (1992) who surveyed economists with regards to their positions in economical debates. When economists were faced with the statement *"A ceiling on rents reduces the quantity and quality of housing available"*, over 90 percent agreed, either completely or with provisions. While this was 30 years ago, it illustrates the historically dominant view that price intervention on the housing market leads to negative side effects. Following the same theme, Jenkins (2009) in a metastudy surveying results from economic journals finds that the prevailing view is one of skepticism. She finds that a majority of papers conclude that rent control brings inefficiencies to the housing market, and moreover is imprecise in its redistributive quality.

Arnott (1995) calls for revisionism on the side of economists with regards to rent control. He argues that the textbook analysis of a price ceiling, and the subsequent intuition with regards to price interventions, is not a suitable tool of analysis when reviewing modern second-generation rent control programs. He goes on to question the nature of the rent control debate: is it merely a charade in that academics and more so, politicians, show off their positions with regards to belief in the free market? With regards to the non-economic discourse, this could certainly be the case.

Sims (2007) utilizes changes in Massachusetts's rent control regime to examine the effect rent control has on rent, maintenance and tenure length amongst other things. He finds statistical evidence that broadly confirms the textbook intuition with regards to rent control, namely that rent control leads to lower rents, a sharper deterioration in quality, an undersupply of rental apartments and longer tenures. He further finds some evidence that rent control on certain units might negatively affect rent levels of uncontrolled units in the same residential area. These spillover effects are further scrutinized by Autor, Palmer and Pathak (2014) looking at the same set of data. They confirm Sims' (2007) view as they find that rent decontrol lead to price appreciation, spilling over to indirectly affect never-controlled units. As properties now reach their "true" price, they go on to calculate the share of deadweight loss through landlord-to-tenant transfer a priori and find it to be substantial. Unexpectedly, they do not however find any evidence that residential investment increased in decontrolled apartments. While investments increased substantially during the period of decontrol, it was not localized to the apartments previously under rent control, which was to be expected.

Albon & Stafford (1990) examine some theoretical models and find that not all intuitive opinions regarding rent control hold when subject to a more evolved model. They expand on Olsen(1969) who predicts that rent control models where the rent for a unit is deregulated at a vacancy won't lead to an undersupply of housing, due to markets adjusting to an equilibrium where prices rise

on the unregulated segment on the market. This type of rent control has for the purpose of this paper for instance been implemented in Ontario. Moreover, they discuss Frankena (1975) who suggests a special case where landlords profits can increase under rent control due to the cost of maintenance dropping more than the revenue from rent, and moreover there would be no excess demand for rentals on the market. This however requires extremely particular circumstances and should mostly be seen as a comment. Of note however is that these papers are not comparable to my approach as they only consider the one time period as opposed to the optimal control problem I aim to employ.

In a more recent paper, Diamond, McQuade and Qian (2019) evaluate rent control akin to Sims (2007) in the setting of San Francisco. When the city in 1994 implemented a law change, a share of the city's inhabitants found themselves under rent control while other tenants with similar characteristics still faced the free market. As such, there was room to interpret data through the lens of a natural experiment. Diamond et al. (2019) find that the implementation led to landlords selling their properties in order to convert them to other ownership forms, reducing, as theorized, the supply of rental housing on the market. This in turn is thought to increase income inequality in the city as a larger share of housing now is made up of high-end condos, affordable only to the rich. However, the law also managed to protect tenants in that they weren't forced out of their homes due to rising prices, an effect that was especially strong for minority groups. In the short run the law thus managed to achieve a goal in making sure current residents weren't displaced by rising prices. They however, in line with the prevailing discourse, theorize that this effect would be more efficiently achieved using other means such as a governmental subsidy program, as that wouldn't have the same adverse effect on landlords and thus the housing supply.

Harris and Rose (2021) examine how different types of landlords behave with regards to maintenance, studying data from Rochester, New York. Unsurprisingly, they find that owner-occupied properties are more likely to be well maintained, as the incentives are quite clear. There are however differences within the group landlords: e.g. those who use property managers are not maintaining properties well compared to other groups.

In a 2015 paper, Lambie-Hansen uses Boston maintenance complaints in relation to foreclosure and examines the claim that sub-par maintenance not only hurts the unit itself, but that there are negative externalities as the neighboring properties also lose value (Lambie-Hansen, 2015). It is furthermore the case that these complaints become more prevalent as a foreclosure case proceeds, affecting the motives of the property owner and their propensity to maintain the unit.

Muyingo (2017) compares properties in the Swedish context owned by private owners on one hand, and public ones on the other, and finds that public owners

to some extent have too high maintenance expenditures. The result is not too surprising as governmental bodies on all levels are subject to profit-maximization to a much lesser extent than private owners. There is however a further battery of hypotheses as to why the data looks that way, including e.g. different accounting customs, differing tenant compositions and timing with regards to revenue streams.

El-Haram and Horner (2002) tries to pinpoint what factors are the most substantial for determining property maintenance costs for the landlord. By surveying actors in Scotland, they try to identify the key factors and find them to largely be non-physical in that the tenants' behaviours play significant roles. For instance mishandling the units they live in or having varying expectations as to what maintenance should be undertaken are singled out as important determinants.

4 Model

4.1 Describing the model

The model used was initially developed by Arnott, Davidson and Pines (1983) to investigate landlords' behaviours with regards to property maintenance. The foundation of the model is that a landlord wishes to maximize their profits by making choices with regards to maintenance. Since there is (1) a causal effect of maintenance on housing quality over time, (2) an effect of quality on rent level and (3) an effect of rent on profits, maintenance plays a role in profits. Causalities (1) and (3) are indisputable, however the second causality might be skewed or even eliminated by a rent control regime. As such, an addition to the model was made by Arnott and Shevyakova (2008) taking this into account.

While the model is a result of previous research, I make modifications as to the functional forms, which complicates the model a bit. Because of its complexity, I go through the solution step by step as to create some resemblance of understanding and intuition with regards to the mathematical and qualitative implications. Since I am to compare non-controlled and controlled maintenance paths, I divide the section accordingly. While the model is the same in essence for the two sections, there are differences in that under rent control, a landlord has incentives to maintain the property only as to raise the quality before negotiating a new nominal rent with a new tenant. As such, a main difference is that a landlord under rent control faces a maximization problem where he has to make decisions with regards to different tenancy cycles, whereas the free market landlord can change his pricing continuously and therefore disregards tenant changes on the whole.

Qualitatively, the model describes the landlord's problem as an optimal control problem, and is solved as such. In a static environment, there is a large number of parameters describing economic relationships, which are then taken

into account when solving the model. As is typical when time is a factor, the landlord discounts future revenue and thus part of the solution is calculating present values of earnings in coming time periods. The problem is mainly solved using Hamiltonian functions and as such the solution is dependent on state and co-state equations, who in turn are dependent on the control variable. In this instance, the state function is the quality of a given property, whereas the co-state function is the marginal value of quality and the control variable, chosen by the landlord, is the maintenance performed in each time period. Solving the system then means to find the optimal maintenance path such that the discounted total profit is maximized. The result differs between free market and rent control environments. Without governmental intervention, there is convergence to a saddle point steady state, where maintenance is constant, as is the quality and its marginal value. With rent control, on the other hand, the solution is a steady state characterized by a cycle where the levels of maintenance differ during a tenancy as to let the starting quality equal the terminal quality, with qualities lower than that during the tenant's stay. The qualitative implication is that under rent control, the landlord has incentives to postpone maintenance until it nears the time for a new tenant, and subsequently an opportunity to agree on a new nominal rent.

4.2 Maintenance as an optimal control problem

The following table describes some of the notation used in the model. While more variables and functions will be introduced, these are the starting parameters. Note that the landlord is able to make choices even before construction of the property.

Parameter	Explanation
q	Quality of housing
m	Maintenance expenditures
q_0	Quality at initial time
$P(q)$	Rent function
ρ	Construction cost per quality unit
R	Land rent
T	Demolition time
r	Discount rate
g	Depreciation function

Table 1: Initial parameters of the model

Quality is an abstract concept and it is thus pointless to try to assign real-world units to it. It is however the case that we can compare properties and assign a higher quality to one of them, thus making quality an ordinal variable treatable akin to utility in standard economic analysis. Quality is important to the landlord through the $P(q)$ function, where the living standard has a direct, assumed

positive, effect on the rent they are able to charge the tenants. It is further assumed that constructing a higher-quality building is more expensive than a lower-quality building. I denote the marginal cost of quality in construction by ρ. Furthermore, since the landlord collects rent in several period, he needs to maximize profit over more than one time period. The terminal time T is then the final period in which he is able to profit, but note that I can let $T \to \infty$ to for instance think of the landlord as an entity such as a housing firm, where profit collection is not limited by the lifespan of a single individual person. Finally, the quality of the property changes between periods depending on the maintenance done as well as the quality in the previous period. Thus there is a depreciation function according to:

$$\dot{q} = g(q, m) \tag{1}$$

The landlord's profit-maximizing is characterized by an optimal control problem:

$$\max_{q_0, m(t), T} \left[\int_0^T e^{-rt} \Big(P\Big(q(t)\Big) - m(t) - R \Big) dt - \rho q_0 \right] (1 - e^{-rT})^{-1} \tag{2}$$

Accordingly, the landlord makes choices in order to maximize his current-valued profit. There is as usual a discounting factor r when evaluating profit in future periods. Note that t is treated as a continuous variable. The inclusion of the $(1 - e^{-rT})^{-1}$ term lets the landlord take into account that a new building could be constructed if the current one is demolished, but note that for large T this term loses its significance as it tends to 1. As with any optimal control problem, the optimization is subject to a number of conditions:

$$q(0) \geq 0, \quad q(t) \geq 0, \quad m(t) \geq 0 \tag{3}$$

$$\dot{q} = g(q, m) \tag{4}$$

$$q(0) = q_0 \tag{5}$$

Quality is measured in positive units and can't be negative. The same applies to maintenance. Equation (4) is simply the depreciation of the state variable q, and equation (5) states that the initial quality $q(0)$ will be equal to the q_0 chosen at construction. This all boils down to a current-valued Hamiltonian:

$$\mathcal{H}(m, q, \phi) = P(q) - m - R + \phi(t) g(q, m), \tag{6}$$

where ϕ is a current-valued co-state variable that can be interpreted as the marginal value of quality. Optimal control theory gives the following condition through Pontryagin's maximum principle:

$$\frac{\partial \mathcal{H}}{\partial m} = -1 + \phi(t) \frac{\partial g(q(t), m(t))}{\partial m} = 0 \tag{7}$$

This implies that for each pair of $(q(t), \phi(t))$, there is a single $m = m^*$ solving this equation, a necessary condition for the optimal control path. Thus, moving on, we can think of m as a function of q and ϕ, and notation-wise, we let $m = m^*(q, \phi(t))$ for the remainder of this solution. Importantly, we can rewrite equation (4) as:

$$\dot{q} = g(q, m(q, \phi)) \tag{8}$$

The next condition for the Hamiltonian is the co-state's motion:

$$\dot{\phi} = r\phi - \frac{\partial \mathcal{H}}{\partial q} \tag{9}$$

$$= r\phi - \frac{\partial P(q)}{\partial q} - \phi \frac{\partial g(q, m)}{\partial q} = \phi\left(r - \frac{\partial g}{\partial q}\right) - \frac{\partial P(q)}{\partial q} \tag{10}$$

We now have motions for q and ϕ. The first one is just an extension of the depreciation function, and the second one is an adjustment mechanism depending on the discount rate, depreciation function and the pricing function. To finish the solution, we need boundary/transversality conditions. I here assume that a property can survive forever as long as it is maintained, and thus let $T \to \infty$. This implies:

$$\phi(0) = \rho \; or \; q_0 = 0 \; and \; \phi(0) \leq \rho \tag{11}$$

$$\lim_{T \to \infty} e^{-rT} H(T) = 0 \tag{12}$$

Equation (11) has the qualitative interpretation that the marginal value of quality should equal its cost at construction, or the house isn't built at all under optimization. Equation (12) is a standard application of optimal control theory. Now, the value of the optimal control program at t given a pair of $(q(t), \phi(t))$ is equal to:

$$V(t) = \frac{\mathcal{H}\Big(q(t), \phi(t)\Big)}{r}, \tag{13}$$

which implies that before constructing the building, the value is equal to the entire program's value less the cost of building the house:

$$V^* = \frac{\mathcal{H}\Big(q(t), \phi(t)\Big)}{r} - \rho q_0. \tag{14}$$

Further solving the problem requires assumptions regarding functional forms and their subsequent effect on the motions of the state- and co-state variables. Assuming there is a stable point for the two states, that point would have to satisfy $\dot{q} = 0$ and $\dot{\phi} = 0$. As such, it is helpful to rewrite equations (8) and (10) under the zero-change condition:

$$g(q, m(q, \phi)) = 0 \qquad (\dot{q} = 0)$$

$$\phi = \frac{\frac{\partial P(q)}{\partial q}}{r - \frac{\partial g}{\partial q}} \qquad (\dot{\phi} = 0)$$

As for functional forms, $P(q)$, the rent function, should qualitatively be increasing in q since a landlord can charge a higher price for a higher quality unit. I will further assume that it suffers from diminishing returns. The motivation for this is that I deem the housing quality's impact on price to only matter to a certain extent. While I model q as the only variate in the P function, there are factors such as geographical locations or infrastructure that are likely to play a large part in pricing, while they are impossible to change through maintenance. I then find it likely that these other factors are complements to quality from a pricing point of view, such that the impact of quality increases on price, while always positive, diminishes if the other factors stay constant. This means:

$$\frac{\partial P(q)}{\partial q} \geq 0 \tag{15}$$

$$\frac{\partial^2 P(q)}{\partial q^2} \leq 0 \tag{16}$$

This could for instance imply a function such as $P(q) = Aq^{\alpha}$ with $\alpha \in (0, 1)$ and $A \geq 0$. As for g, the intuition is a bit more complicated. Simple enough is the fact that the more maintenance done, the higher the quality change should be. Again, it makes sense for this return to be diminishing as you can only improve a property's quality through maintenance to a certain extent, implying:

$$\frac{\partial g(q, m(q, \phi))}{\partial m} \geq 0 \tag{17}$$

$$\frac{\partial^2 g(q, m(q, \phi))}{\partial m^2} \leq 0 \tag{18}$$

Similarly, I will assume that the amount of maintenance needed to keep a constant level of quality increases with quality. Thus, ceteris paribus, the quality of a property will depreciate at a higher rate as quality increases, i.e:

$$\frac{\partial g(q, m(q, \phi))}{\partial q} \leq 0 \tag{19}$$

We can make further assumptions regarding the functional form of g. I assume that it is separable in q and m, and a function that would satisfy equations (17)-(19) could then be e.g:

$$g(q, m) = -Bq + Cm^{\beta}, \tag{20}$$

with $B, C \geq 0$ and $\beta \in (0, 1)$. This functional form implies:

$$\frac{\partial g}{\partial m} = C\beta m^{\beta - 1}, \tag{21}$$

which when placed in the necessary condition from equation (7) gives:

$$1 = \phi C \beta m^{\beta-1} \implies m^* = (\phi C \beta)^{1/1-\beta} \tag{22}$$

Note that this optimal m contains neither quality nor any of the parameters from the pricing function. It is however indirectly affected through ϕ. Rewriting the zero-change conditions with these functional forms, we have:

$$-Bq + C\Big(\phi C \beta\Big)^{\beta/1-\beta} = 0 \implies \phi = \Big(Bq\Big)^{1-\beta/\beta} C^{-1/\beta} \beta^{-1} \implies$$

$$\implies \frac{\partial \phi}{\partial q} = B^{1-\beta/\beta} C^{-1/\beta} \beta^{-1} \frac{1-\beta}{\beta} q^{1-2\beta/\beta} \geq 0 \text{ for } \dot{q} = 0 \tag{23}$$

$$\phi = \frac{A\alpha q^{\alpha-1}}{r+B} \implies \frac{\partial \phi}{\partial q} = (\alpha - 1)\frac{A\alpha q^{\alpha-2}}{r+B} \leq 0 \text{ for } \dot{\phi} = 0 \tag{24}$$

What equations (23) and (24) practically say is that we can draw a phase diagram with different signs of the slopes for the two lines representing $\dot{q} = 0$ and $\dot{\phi} = 0$. The assumption that the functions intersect is not derived from the mathematics but is rather done for modelling purposes: were it not the case, we would not have a stable solution of the system.

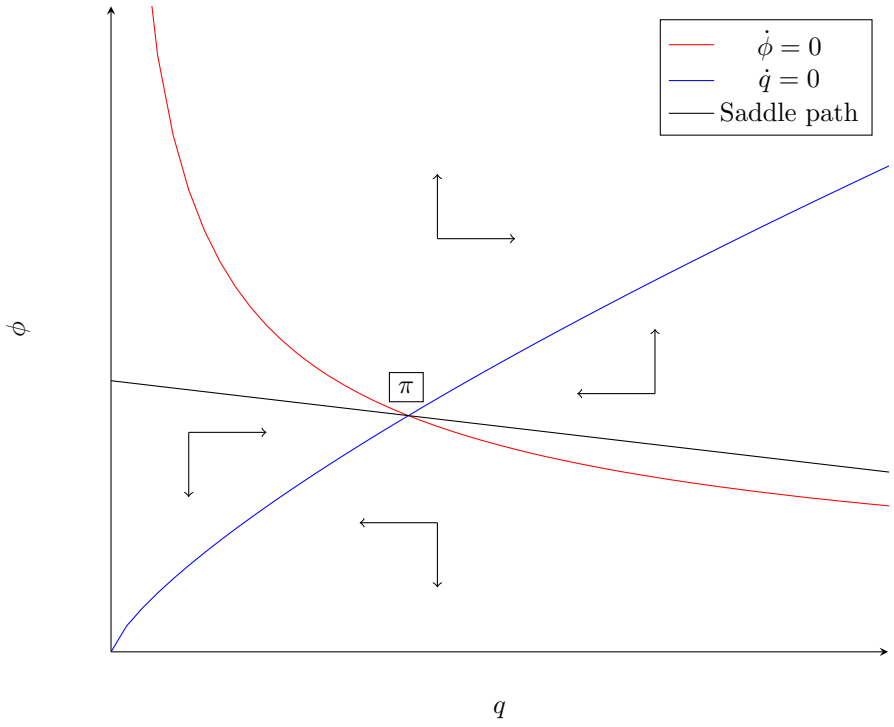


Figure 1: Phase diagram in the $q - \phi-$plane.

As is obvious from equation (10) with a negative $\frac{\partial g}{\partial q}$, all points above the $\dot{\phi} = 0$ line will have upwards motions and vice versa. Similarly, equation (20) with its negative derivative of q yields leftwards motions for all points to the right of the $\dot{q} = 0$ line, and vice versa. There is subsequently a saddle path solution and a single stable solution to the system, namely the saddle point π where $\dot{q} = \dot{\phi} = 0$. At that point, in terms of parameters, the values of q, ϕ and m are as following:

$$q = D^{\frac{\alpha}{\alpha\beta - 1}} \tag{25}$$

$$\phi = \left(BD^{\frac{\alpha}{\alpha\beta - 1}} \right)^{1-\beta/\beta} C^{-1/\beta} \tag{26}$$

$$m = B^{\frac{1}{(1-\beta)\beta}} C^{-1/\beta} D^{\frac{\alpha}{\beta(\alpha\beta - 1)}} \tag{27}$$

where D collects parameters according to:

$$D \equiv \frac{r + B}{A\alpha\beta} B^{1-\beta/\beta} C^{-1/\beta} \tag{28}$$

4.3 Maintenance under rent control

Enter second-generation rent control with tenancy decontrol. The P function is no longer functioning as an incentive to keep quality up during a tenancy, but is used between tenants to beef up the initial agreed rent. Let p_s denote starting rent at a tenancy, L total length of the tenancy and u number of periods into the tenancy, starting at s. There is some rent control function $F(p_s, u)$ such that the maximum allowed rent at a certain time is dependent on the agreed starting rent as well as how much time has passed since moving in. It is assumed that the landlord charges the maximum allowed rent in each period, i.e. F, because if the rent control didn't affect his pricing, there would be little point with this analysis. The landlord is thus interested in maximizing the discounted value:

$$\int_0^L F(p_s, u) e^{-ru} du \tag{29}$$

Initially assuming that L is exogenous (i.e. the landlord can't arbitrarily evict a tenant) the only variable a landlord can affect is p_s. Now, the solution starts by showing what happens if L, q_L and q_s are given. This is done in part A.1 of the appendix and shows how the maintenance path is set given that some maintenance must be done to reach the terminal quality q_L. Now, assuming rent control is formulated in such a way that the nominal rent can be set freely according to the P function, this expression is equal to:

$$\int_0^L F\Big(P(q_s), u\Big) e^{-ru} du \tag{30}$$

Let $J(q_s, q_L, L)$ denote the maximum value of a program taking these variables as given, using the solution from section A.1. We have:

$$\frac{\partial J}{\partial q_s} = \phi(0) \tag{31}$$

$$\frac{\partial J}{\partial q_L} = -\phi(L)e^{-rL} \tag{32}$$

$$\dot{\phi} = \phi\Big(r - \frac{\partial g}{\partial q}\Big) \tag{33}$$

Note that given that $\frac{\partial g}{\partial q} \leq 0$, equation (29) implies that $\phi = 0$ only if $\dot{\phi} = 0$, which means that there is now no possibility to draw a saddle point in the interior of a phase plane as above. Moving on, it doesn't really make sense to take q_L as given: a landlord can affect the quality at terminal time through maintenance during the tenancy. If we let $Z(q)$ denote the value of the discounted revenue from letting the property to a tenant for a period, we can define a value function $V(q)$ such that:

$$V(q_s) = Z(q_s) + \max_{q_L} \Big(J(q_s, q_L, L) + V(q_L)e^{-rL} \Big) \tag{34}$$

That is, the value depends on the property value, the value of the rent and the discounted value of the value function at terminal time. It is thus reflexive. The landlord maximizes this by deciding q_L through maintenance paths. F.O.C with regards to terminal quality, using equation (32):

$$\frac{\partial V(q_s)}{\partial q_L} = -\phi(L)e^{-rL} + \frac{\partial V(q_L)}{\partial q_L}e^{-rL} = 0$$

This implies:

$$\frac{\partial V(q_L)}{\partial q_L} - \phi(L) = 0 \implies \frac{\partial V(q_L)}{\partial q_L} = \phi(L) \tag{35}$$

We further need to differentiate the value with regards to starting quality:

$$\frac{\partial V(q_s)}{\partial q_s} = \frac{\partial Z(q_s)}{\partial q_s} + \frac{\partial J(q_s, q_L, L)}{\partial q_s} = \frac{\partial Z(q_s)}{\partial q_s} + \phi(0) \tag{36}$$

Before constructing a house, the landlord further needs to decide the construction quality q_c. Note that $q_c = q_s$ for the first tenant moving in to the property. The landlord thus maximizes through setting q_c as to maximize:

$$V^* = V(q_c) - \rho q_c, \tag{37}$$

which implies the first order condition of:

$$\frac{\partial V^*}{\partial q_c} = \frac{\partial V(q_c)}{\partial q_c} - \rho = \frac{\partial Z(q_c)}{\partial q_c} + \phi(0) - \rho = 0 \implies \phi(0) = \rho - \frac{\partial Z(q_c)}{\partial q_c} \tag{38}$$

This of course resembles any given model from an undergraduate textbook: the marginal cost of quality needs to equal its marginal value. The marginal value

in this equation is split between Z and ϕ: as Arnott and Schevyakova (2014) put it, Z' represents the marginal value of quality before the contract is signed, ϕ the marginal value once the contract is signed. This in combination with equation (33) means that we won't have an interior solution as we did without rent control: we only have $\dot{\phi} = 0$ when $\phi = 0$, and we also have discrete jumps in ϕ according at the time of the contract's signing.

While we can't have a stable saddle point, we can have a steady state cycle where we are constantly in motion, but in an infinitely repeating manner. However, for there to be such a steady state, the quality of a property at the start of a tenancy needs to equal the quality at the start of the next tenancy. Since it isn't efficient to keep a property vacant, this further implies that the starting quality of a tenancy equals the terminal quality of a tenancy, although the quality differs during said tenancy. In algebraic form, we in steady state have some:

$$q^* = q_s = q_L \tag{39}$$

This in turn implies that the value of a optimized program equals:

$$V^* = (1 - e^{-rL})^{-1}\Big(Z(q^*) + J(q^*, q^*, L)\Big) \tag{40}$$

Qualitatively, this implies that since the landlord wants the property to have the same level of quality at the start and end of a tenancy, he needs to perform maintenance, but since depreciation is higher for higher quality properties, he now has incentives to postpone maintenance to the end of the tenancy. This is also shown in the appendix section A.1.1. In a phase plane, we have now upwards motions for all positive ϕ, whereas the g function giving $\dot{q} = 0$ hasn't changed.

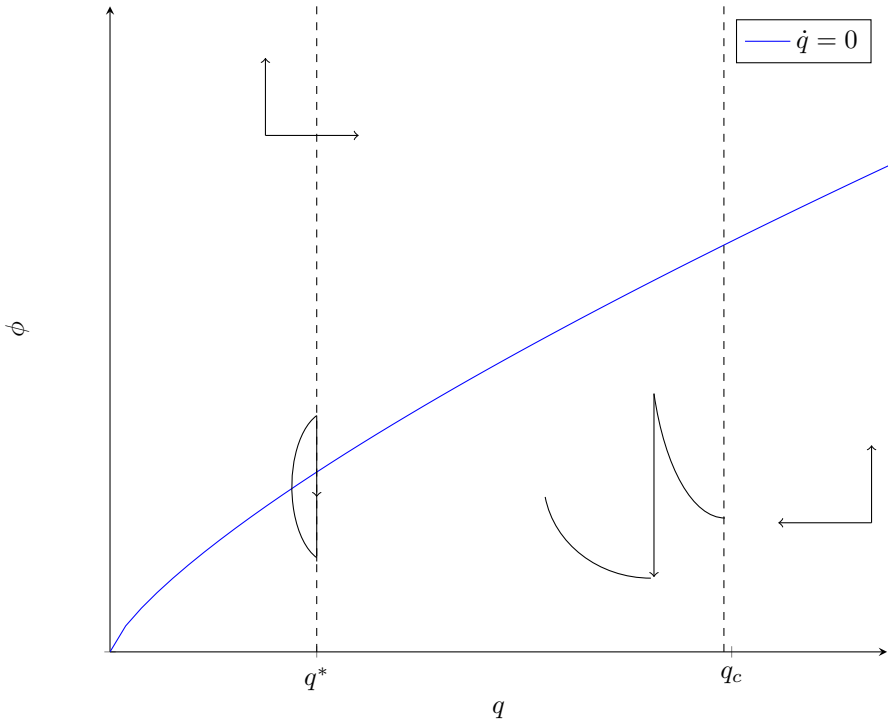


Figure 2: Phase diagram in the $q - \phi-$plane with rent control

Above phase diagram aims to illustrate the motions towards the steady state from the time of construction. The initial quality q_c is high and ϕ is positive, thus we move northwest such that quality is decreasing but the marginal value of quality is increasing. At the end of the tenancy, the marginal value ϕ drops discretely when the new contract is signed, thus creating a new northwestern motion. This continues until we reach the steady state cycle around q^*, where we have decreasing quality towards the start of a tenancy but increasing towards the end. Marginal value is increasing throughout, but drops discretely between contracts. Since optimal maintenance is a positive function of ϕ, this is again in line with previous reasoning: the incentives to maintain and increase quality grow as the tenancy nears an end, whereas there is a diminished incentive to maintain in the time shortly after a contract is signed.

We still have:

$$m^* = (\phi C \beta)^{1/1-\beta} \tag{41}$$

This means that the steady state level of maintenance under rent control compared to the free market level depends on the rent control system's ϕ's relative position to the singular ϕ from the initial saddle point. As instituting rent control in terms of the phase diagram means altering the $\dot{\phi} = 0-$line such that

all $\dot{\phi}$ are positive, we would initially expect an upwards motion in ϕ and as such a higher level of maintenance directly when implementation hits, which also means increases in quality. This will only be temporary though, as there then will be discrete drops in ϕ such that we periodically end up below the $\dot{q} = 0-$line, where maintenance is low enough for quality to depreciate. The sawtooth motion again moves towards the steady state cycle of Figure 2. The motion from free market to rent control is illustrated below in Figure 3. Again, note that the $\dot{\phi}-$line disappears when rent control is implemented.

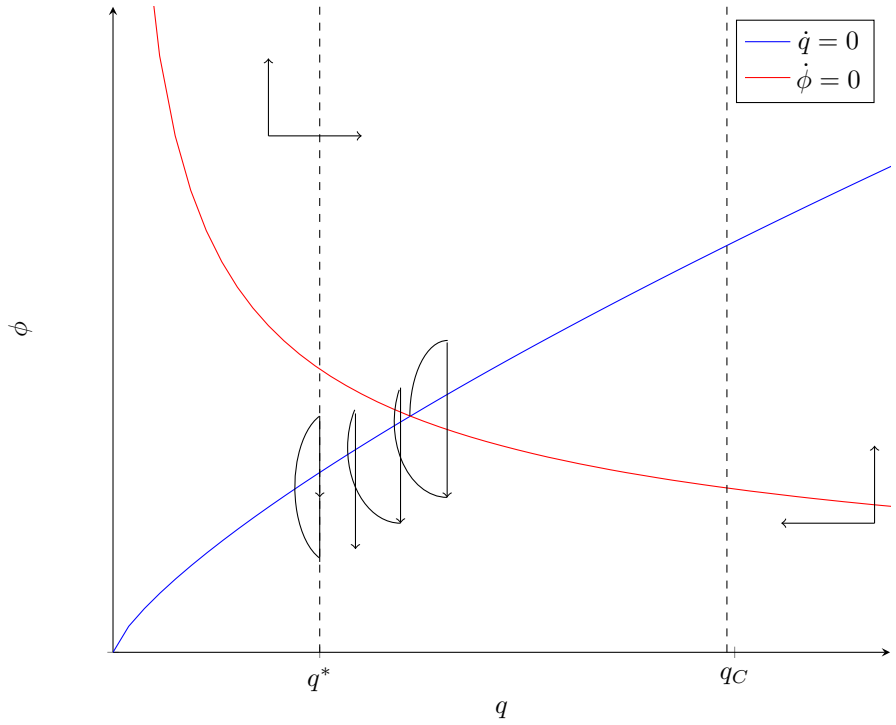


Figure 3: Moving from a free market to rent control

However, looking at a population such as the entirety of Canada, we will indirectly observe a large number of landlords' data and thus a large number of overlapping tenancies, and as such we would expect the observed value to be that of the mean. I am thus unable to see the cycle, but only aggregate movements. In above figures, the steady state cycle is drawn in such a way that the steady state quality is lower under rent control than under free market, whereas the average value of ϕ and thus maintenance is also lower, while there can be instances of higher than free market maintenance towards the end of a rent control cycle. These qualities are intuitive, but they are mathematically dependent on the parameters chosen. While I will not use numerical examples, Arnott and Schevyakova (2014) perform calculations in their framework and

find these properties to hold for reasonable parameter choices. As I have altered their model a bit in terms of functional forms, the results are not directly transferable, but the qualitative properties are theoretically sound and should be analogous in my setup. This further implies the basis for the econometrics in the following section: ceteris paribus, rent control should imply a lower steady state level of maintenance expenditures, while there can actually be short term increases directly following the implementation. The magnitude of these short term increases would then theoretically depend on the average temporal position in the tenancy cycle: if the mean contract has just started, there will be a long period of quality increases, if it's soon due, the discrete drop in ϕ and subsequent quality depreciation will follow before soon.

5 Data

The data used is provincial Canadian maintenance and rent control data spanning from 1968 to 2019. The choice of Canada is due to the provinces themselves being able to decide on their rent control policies. This means that rent control programs differ *between* provinces when e.g. Ontario and Saskatchewan choose different systems, as well as *within* a province such as Manitoba switches back and forth over time. The result is thus panel data and can be analyzed as such. The Canadian territories of Yukon, Nunavut and Northwestern Territories are excluded from the analysis due to their lack of sovereignty. They would also be unfit as they are urbanized to a much lesser extent than the provinces. The time limit set is mainly for data considerations. Before 1968, it is hard to find complete data for all states, skewing the balance of the panel data analysis. As shown later, a coefficient of interest will also suffer from some bias, where its consistency serves as further motivation for a lot of observation as the bias then will skew the regression to a lesser extent. The end date of 2019 is set to avoid the potential shocks to the system inflicted by the covid-19 pandemic, as it led many provincial governments to adopt crisis measures that are inappropriate to analyse through the same lens as the planned regulations and deregulations of the fifty or so years prior.

The section is structured as following: the initial discussion will regard rent control regimes in the different provinces over time, which will be followed by a description of the maintenance data as well as econometric output. The section is then concluded by integrating the results with the model presented in the previous section.

5.1 Rent control

The rent control systems in the provinces throughout the time period is summarized in the table below in a simple way. As there are many forms of rent control, a more thorough discussion will follow in the coming paragraphs.

Province	Rent control
Alberta	1976-1980
British Columbia	1974-1984, 1992-2002, 2002-
Manitoba	1976-1980, 1982-
New Brunswick	Unregulated
Newfoundland and Labrador	Unregulated
Nova Scotia	1975-1993
Ontario	1975-
Prince Edward Island	1968-
Québec	Unregulated
Saskatchewan	Unregulated

Table 2: Rent control over time in Canadian provinces

5.1.1 Alberta

Alberta, with its two large cities of Calgary and Edmonton, does not currently have a rent control system limiting neither nominal rent nor increases (Government of Alberta, 2021). It is however the case that the rent only can be increased once per twelve month period. There is also a soft cap on rent increases as there is a governmental guideline on appropriate increases and if the landlord wishes to increase the rent even higher, they need to submit an application to do so. As such, while the market forces are relatively unregulated, there is a governmental control system in place to hinder unfair rent shocks.

Historically, there has been rent control in place between 1976 and 1980 (Dillon et al., 1982). A second-generation program, it allowed for rent increases between 8 and 10 percent in 1976, and was adjusted in the following years leading up to the complete decontrol of 1980. Worth noting, and a common theme with regards to many provinces, is that Canada was struggling with high inflation during the 1970s. A such, many provincial governments felt it justified to adopt extraordinary economic measures. Alberta's rent control was one such step where it was articulated from the start that the system was a temporary one to combat the acute problems.

5.1.2 British Columbia

British Columbia, centered around Vancouver, has a second-generation rent control system in place. Once a year, a figure is set in law as the maximum allowed rent increase (Government of British Columbia, 2021). This figure is closely tied to the local consumer price index for the British Columbia. There is further no way for the landlord to retroactively raise rents, as only the current year's figure is the allowed one.

This system was put in place 2002 and replaced an earlier soft rent control system. Between 1992 and 2002, there was no formal figure for the landlords

to adjust their increases to, but there was a governmental body to which any tenant could turn to for challenging a rent increase. The system was such that the burden of proof with regards to the increase being appropriate was put on the landlords, and it could as such be costly for a landlord to increase rents freely. As such, while there again was no formal ceiling on rents, it would be inappropriate to classify British Columbia as an unregulated market during this period. This was in turn preceded be a period of complete decontrol, where between 1984 and 1992, the market was left to its own (Landlord BC, 2019). The decade before that, 1974-1984, had a second-generation system capping increases, again to be seen in the context of Canadian inflation during the period. Before 1974, there were no rent control regulations (Landlord BC, 2019).

5.1.3 Manitoba

Manitoba, with its largest city being Winnipeg, has a rent control profile similar to that of British Columbia. Rent controls are capped, and the figure is tied to the provincial CPI (Government of Manitoba, 2021). It is however the case that landlords can submit an application to a governmental body known as the Residential Tenancies Branch, and if approved they can raise rents above the guideline. Again, rent increases are limited to one per year.

The current system has been in place since 1982, but has gone through some modifications, notably tying the figure to CPI and allowing exemptions from the program (Grant, 2011). In a short two-year period between 1980 and 1982, there was complete decontrol, which was preceded by a four-year period of rent controls of the second generation. Worth mentioning is that the decontrol of 1980 was announced in 1978 and was preceded by partial decontrol of some markets (Grant, 2011). Pre-1976, there were no rent control systems in place.

5.1.4 New Brunswick

New Brunswick has no rent control system and as such a landlord may increase rents however they like. A tenant is however entitled to a period of notice before the rent increase, and the length of the period depends on the nature of the contract. There is also a system such that if a landlord raises the rent of a single apartment, they need to raise all rents in the same property with a similar percentage in order to combat (non-)preferential treatment (Government of New Brunswick, 2021). They have no history of rent control during the analysed period.

5.1.5 Newfoundland and Labrador

The province of Newfoundland and Labrador does not have any rent control system, nor have they had one for the last fifty years. Like in New Brunswick, tenants are however entitled to a period of notice before a rent increase kicks in (Government of Newfoundland and Labrador, 2021).

5.1.6 Nova Scotia

Nova Scotia is currently under a rent control system enforced to combat economic hardships stemming from the covid-19 pandemic, but as of 2019, it had been decontrolled since 1993. In the nearly two decades preceding the deregulation, there was a second-generation rent control system instated by the 1975 Rent Review Act (Halifax Regional Council, 2020). The law introduced a centrally decided maximum allowed percentage figure increase like many other provinces, but it was however not tied to any CPI measures but instead decided on an annual basis by a governmental body. The implementation of the 1975 measure is again tied to the economic instability of the Canadian 1970s. Before 1975, however, there were no enforced rent control measures.

5.1.7 Ontario

Ontario is the most populous province of Canada, containing the largest city in Toronto, the nation's capital in Ottawa and other large cities such as Hamilton and London. It is also the largest province economically, and as such measures taken in Ontario are likely to have a relatively large impact on the Canadian economy as compared to smaller provinces such as Prince Edward Island. Possibly because of the high stakes, the rent control systems in Ontario are, and have been, subject to a larger extent of scrutiny than the other provinces, often resulting in complex systems that likely bring with them substantial administrative expenses.

Just as in Nova Scotia, there is currently a temporary measure in place as a direct consequence of the covid-19 pandemic, acting as a rent freeze capping the increase to 0 percent (Government of Ontario, 2021). The norm, however, has been since 1975 for Ontario residents to face a standard second generation rent control system with a maximum allowed percentage increase (Smith, 2003). The system has however undergone many changes since 1975. It was not until 1986 that the figure was tied to provincial CPI, earlier being decided by a governmental body according to other factors. In 1998, there was a sharp turn towards deregulation as new buildings, retroactively from 1991, were now exempt from rent control. Similarly, any vacancy in existing properties under rent control made these properties exempt. Furthermore, a pass-through system was put in place such that landlords could increase rent further by declaring their capital expenses as reasons for an increase (Mendonça-Vieira, 2018). Similar measures were taken in 1992, although to a limited extent as the new building exemption only was valid for a five-year period and the pass-through didn't account for 100 percent of the capital expenses.

This system was in place until 2017, when all units again were subject to the 1986 system, rent control tied to CPI (Government of Ontario, 2017). This means that in 2016, the only properties under the system were effectively the properties constructed before 1991 which hadn't been vacant since 1998. This of

course is such a sharply defined subset of tenants that the majority of properties de facto were decontrolled by the 2017 measure. The econometric modelling difficulties stemming from this are obvious, but will be discussed later. Prior to 1975, there were no rent control measures in place.

5.1.8 Prince Edward Island

Prince Edward Island has a second-generation rent control scheme in place, but unlike the other provinces, the increases are tied to the units, not the tenants. This means that a landlord can't change the nominal rent between tenancies as they would be able to in e.g. Manitoba. Furthermore, this means that landlords have no incentives for tenant turnover (read evictions) as the revenue is only affected by whether or not there is a tenant or not. This system has been in place since 1976 and was preceded by an even harsher system of rent freezes (Canada Mortgage and Housing Corporation, 2020).

5.1.9 Québec

Québec does not have any formal rent control, nor have they had any during the analysed period. There is however an informal system where a governmental body provides calculation models for tenants and landlords to use in order to arrive at appropriate rent increases (Gouvernement du Québec, 2021). This system is not however legally binding, and a landlord can de facto increase rent freely. As in other provinces, there is however a limit of one rent increase per year, and the tenant is entitled to a period of notice (Gouvernement du Québec, 2021).

5.1.10 Saskatchewan

Saskatchewan does not have any rent control limiting the amount by which a landlord may increase rent, but again there is regulation with regards to notice as well as a limit of one raise per year. For contracts regarding a fixed term, however, the landlord is not allowed to raise rent at all for the duration of the contract. There has historically not been any rent control in place for periodic leases in the analysed time frame.

5.2 Maintenance data

The main data source used is Statistics Canada, the federal agency responsible for production of statistics. This includes, but is not limited to, calculations regarding population, GDP, inflation measures (including provincial CPI) and, importantly, data on maintenance. Maintenance expenditure is collected through the quarterly published statistical program *National Gross Domestic Product by Income and by Expenditure Accounts* combining surveys with regards to both governmental bodies and private actors. The maintenance data is presented as the total expenditure in Canadian 2002 dollars, and is further split by geographical areas and ownership structure. By ownership structure, it is

possible to separate the landlord- and tenant-occupied properties' maintenance expenditures from the owner-occupied properties. It is not however possible to separate the maintenance expenditures in vacant rental apartments from the occupied ones. My assessment is however that this flaw should be insignificant with regards to the econometrics. The presented model implies that all landlords should undertake maintenance under an on-going tenancy as to minimize the time the property is vacant, which is supported by the fact that vacancy rates are very low for most observations over province and time. A problem with the data is however that the provincial CPI measures are not available for the entire period, but only for the last decades. Thus, the adjustment for inflation is done using Canada's CPI and might thus skew the data with regards to different price levels in different provinces. While I do not think the impact on the analysis is affected to significant degree, it is well worth to keep in mind. Overall, maintenance expenditures have evolved in a similar pattern throughout the provinces, as shown in figure 4 below.

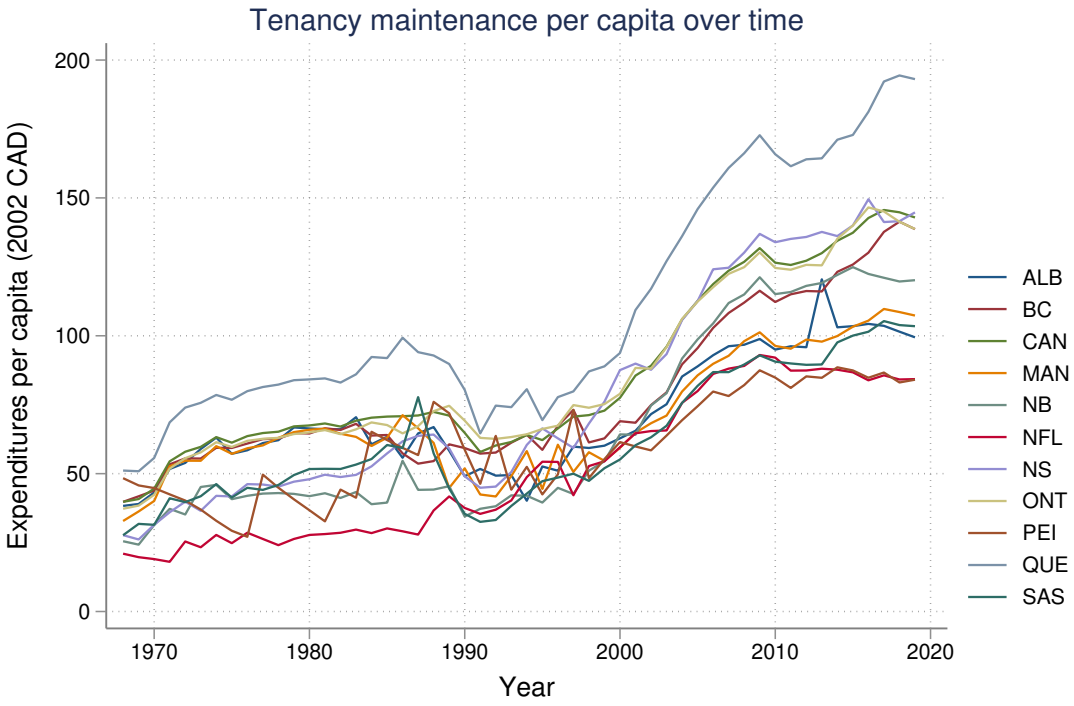


Figure 4: Tenancy maintenance per capita over time

Looking at the time series, they can broadly be said to follow similar structures, being weakly increasing up until the mid-90s when they all seem to trend up-

wards more sharply until the late 00s, then they again stabilize. The period between 1990 and 2010 thus seems to be of special interest. It is of note that the early 90s were characterized by a recession in Canada, as was of course the late 00s due to the financial crisis. This can be contrasted with the share of landlord- or tenant-occupied maintenance expenditures over total maintenance expenditures throughout the time period:

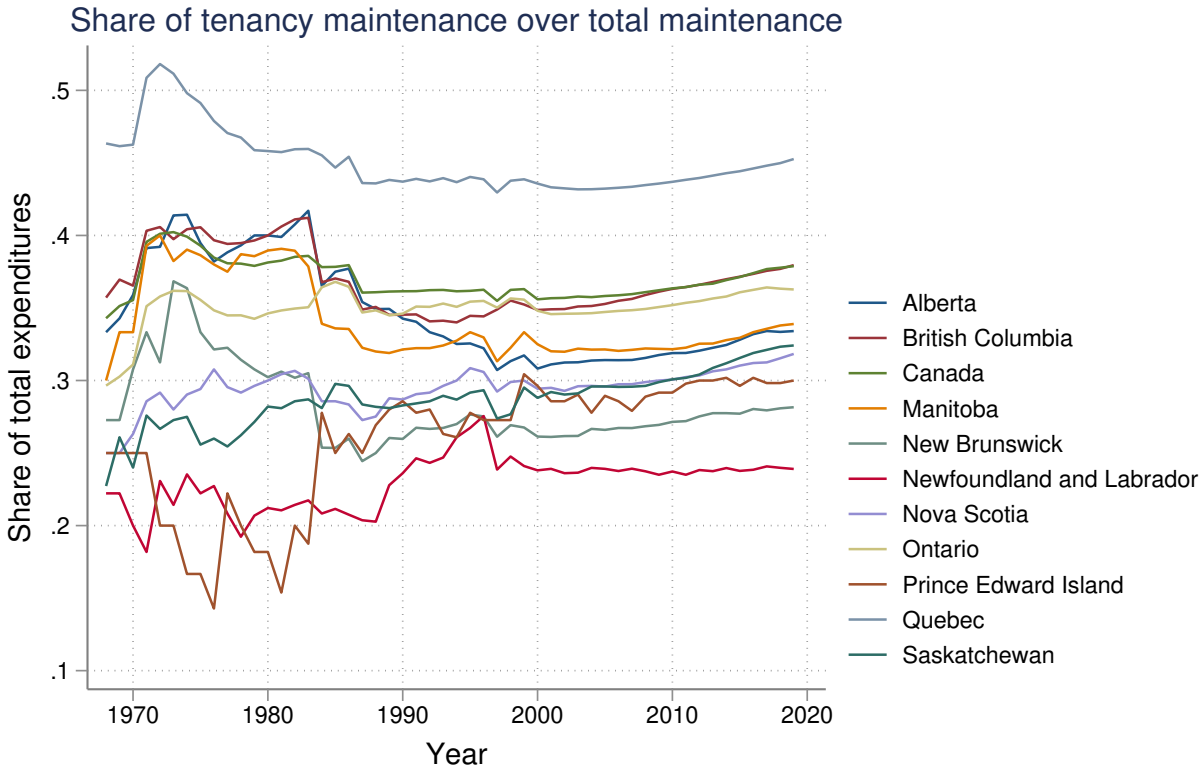


Figure 5: Share of tenancy maintenance over total maintenance

There doesn't at a first glance look to be any deterministic trends present, nor are any sharp breaks in the 90s or late 00s glaringly obvious. Since the drastic changes of figure 4 are not present in figure 5, we can deduce that the non-tenancy maintenance evolved according to similar patterns as tenancy maintenance. This in turn implies that the background variables causing the variation in figure 4 are not mainly targeting rental contracts, but seem to affect the entire housing market. A Levin-Lin-Chu panel unit root test (2002) can't reject the null that the panel contains unit roots. Would it be the case that the shares are represented by unit roots, we would expect shocks to the system to

have permanent effects in that there would be no reverting to a steady state post-shock. The same goes when testing the stationarity of the maintenance expenditures per capita. As such, there is reason to question the validity of statistical regressions as the presence of unit roots would induce bias. There is thus reason to evaluate whether or not the first difference of the maintenance expenditures could serve as a proper dependent variable. Indeed, the LLC unit root test strongly rejects the presence of unit roots when examining Δy_{it}, and as such it will be a statistical improvement. Equivalently, I state that maintenance per capita is integrated of order 1.

Confirming suspicions about autocorrelation, a series of calculations with regards to autocorrelation and partial autocorrelation are done for each of the ten time series. In all cases, the geometric decay of the autocorrelation function and the singular spike of the partial autocorrelation function suggests that all ten provinces' maintenance expenditures are characterized by AR(1) processes (see e.g. Enders(2015)) with a positive autocorrelation coefficient (see appendix figures A1 and A2).

Econometrically, an initial model that we want to estimate is:

$$y_{it} = \gamma C_{it} + \delta y_{i,t-1} + a_i + \lambda_t + \boldsymbol{\beta}\mathbf{X_{it}} + \varepsilon_{it} \tag{42}$$

where C_{it} assumes 1 or 0 depending on whether or not province i has rent control at time t. a_i and λ_t allow for individual effects and time effects, and $\mathbf{X_{it}}$ is a matrix of control variables differing in both time and across provinces. This is however problematic due to the unit root's possible presence: we can't rule out $\delta = 1$. If we were to have $\delta \geq 1$, we would no longer have stochastic error terms. Any coefficients estimated with OLS in such a system would then suffer from bias: the coefficient γ, which is what's of interest, would be the result of a spurious regression. The solution is to use changes in maintenance per capita as opposed to the actual levels, reducing the risk of the regressions being spurious, in line with e.g. Granger and Newbold (1974). As such, we investigate the first difference:

$$\Delta y_{it} = y_{it} - y_{i,t-1} = \gamma \Delta C_{it} + \delta \Delta y_{i,t-1} + \Delta\lambda_t + \boldsymbol{\beta}\Delta\mathbf{X_{it}} + \Delta\varepsilon_{it} \tag{43}$$

While we now have stationary residuals, there is another problem in that there is endogeneity introduced. $\Delta y_{i,t-1}$ and $\Delta\varepsilon_{it}$ are both functions of $\varepsilon_{i,t-1}$, which means that there is bias in estimating δ, which in turn means that bias spills over to γ. While we can't eliminate this bias, there is nothing theoretically preventing estimation of γ to be biased but consistent. A cause of concern, this is one of the main reasons for the relatively longitudinal balance of the panel, as more observations then should minimize this bias given an assumption of consistency. Note that since a_i is time-invariant, $\Delta a_i = 0$ and can thus be excluded from the equation.

I start by looking at the case where we ignore **X** altogether. I also run a regression including a dummy for being in the period between 1990 and 2010. Note that Canada as a country of course is dropped for the statistical analysis. In the below table, regressions (1) and (2) use a fixed effects model, where (3) through (4) try a random effects model. Note that since the dependent variable is a difference, the interpretation of the constant is actually meaningful: it is a coefficient representing a deterministic time trend.

	(1)	(2)	(3)	(4)
	Δ y	Δ y	Δ y	Δ y
ΔControl	-0.698	-0.701	-0.689	-0.691
	(-1.07)	(-1.75)	(-0.97)	(-1.47)
L.Δ y	-0.0974	-0.111	-0.0863	-0.0999
	(-1.02)	(-1.23)	(-0.91)	(-1.10)
1990-2010		1.445***		1.430***
		(6.02)		(5.99)
Constant	1.887***	1.304***	1.867***	1.291***
	(11.43)	(6.68)	(17.20)	(8.60)
Observations	500	500	500	500

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 3: Regression results with dummy

As is obvious from the above regressions, rent control has a negative coefficient in all regressions, but is not statistically significant. The deterministic trend seems to have a positive effect which in turn seems to be stronger between 1990 and 2010. Standard errors are clustered by province, and trying a "random effects"-model does not change any qualitative conclusions. As we are interested in the actual magnitude of γ, we from now on restrict ourselves to the fixed effect model. This approach is further confirmed by conducting a Hausman test.

Why then is the deterministic trend there, and why does it change in that time period? It of course isn't time itself that's forcing the expenditures up, but other economic variables that have increased with time and as such affect the specification through t. A natural suspect is urbanization. Given that the share of tenancy properties' maintenance of total maintenance hasn't changed substantially, there is reason to suspect that when people move into the cities, they to a larger extent live in properties where maintenance is undertaken and recorded. It is not hard to imagine an owner-occupied rural household doing maintenance work on their property without recording it with any authority. As these people move into urban areas, maintenance is perhaps to a larger degree

undertaken in a more formal way, allowing for better data collection. Indeed, looking at Canada's urbanization rate, there is a positive trend with a sharper slope between 1990 and 2010:

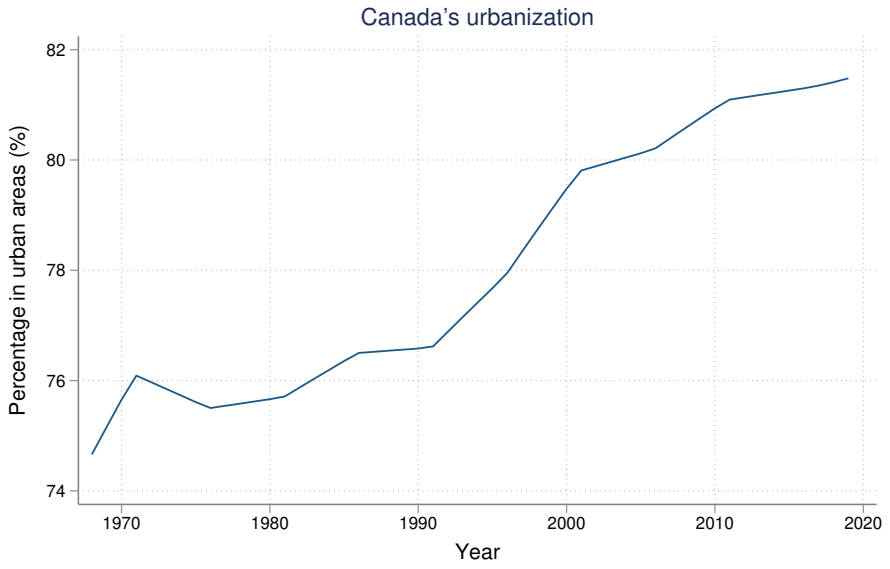


Figure 6: Percentage of Canadians in urban areas over time

There are however data availability problems with regards to urbanization. Since such a large share of the population lives in Ontario and Québec, their urbanization rates are going to dominate the national average. I have not been able to find data regarding urbanization in each province for each time period, but only for discrete times. My solution is thus to scale the national urbanization rate for each time period according to the provincial urbanization at a single time period. This is a valid approach given that all provinces have experienced similar trends, but it is natural to expect the trends to differ between provinces. As such, I deem the coefficient with regards to urbanization with scepticism, but as it's not the main interest of the analysis, I evaluate it to suffice as a control variable.

	(1) Δ y	(2) Δ y
ΔControl	-0.410	-0.484
	(-0.67)	(-1.00)
ΔUrbanization	6.209**	4.649*
	(4.01)	(2.59)
L.Δ y	-0.0988	-0.107
	(-1.03)	(-1.15)
1990-2010		0.881*
		(2.68)
Constant	1.223***	1.034**
	(5.17)	(4.55)
Observations	500	500

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 4: Regression results with urbanization

Running a regression using first differences of scaled urbanization yields significance for urbanization, and weakens the effect of the deterministic time trend, which is what is to be expected. The rent control dummy is still insignificant but negative. It is further an issue that a dummy variable represents all types of rent control, when in fact we would expect different magnitudes of adverse effects depending on the harshness on the controls. I subsequently also model the rent control according to its type, creating four categories: free market, soft rent control, second-generation tenancy rent control and second-generation unit rent control. While these are increasing in harshness, they are modelled as dummies as it wouldn't make sense to treat them as ordinal since e.g. the difference between free market and second-generation tenancy rent control doesn't necessarily equal twice the difference between free market and soft control. However, since Prince Edward Island is the only jurisdiction using unit rent control, there exists perfect collinearity in the fixed effects model as whatever effects unit rent control has are hidden within the individual effects with this specification. Prince Edward Island is subsequently dropped for this analysis. Specifically, I want to model:

$$\Delta y_{it} = \lambda + \gamma \Delta C_{it} + \boldsymbol{\beta} \mathbf{D_{it}} + \boldsymbol{\theta}(\mathbf{D_{it}} * \Delta C_{it}) + \delta \Delta y_{i,t-1} + \psi \Delta U_{it} + \Delta \varepsilon_{it}, \quad (44)$$

This allows for interaction effects as well as vertical changes, as I expect the different kinds of rent control to have instantaneous as well as long-term effects.

Again, note that since the dependent variable is the first difference, a change in constant translates to a change in slope for the non-differenced time series, as the levels function is the primitive of the changes function.

	(1) Δ y
Soft	-0.606
	(-0.47)
Tenancy	-1.370
	(-1.18)
ΔControl	-4.431***
	(-7.10)
Soft × ΔControl	9.270***
	(6.49)
Tenancy × ΔControl	3.598*
	(2.75)
ΔUrbanization	5.651**
	(3.43)
L.Δ y	-0.00929
	(-0.11)
Constant	1.633***
	(5.17)
Observations	450

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 5: Regression results with categorical variables

The results in above table require careful interpretation. Due to the nature of the regression, there are both instant effects as well as long-term trend shifts. First note that the data is structured such that a shift in rent control regime, i.e. rdiff, is a discrete variable that takes the value 1 in a single time period only to revert to zero again, a pulse dummy of sorts. On the other hand, the dummies indicating the type of rent control are there continuously. This means that for a given change in rent control system to system $k \in (1, 3)$, the instant effect of the shift is equal to $\gamma+\beta_k+\theta_k$. However, since ΔC_{it} reverts to zero, the long-term effect is limited to β_k. As such, the results above need to be combined for interpretation. Ceteris paribus, shifting from a free market regime to soft rent control invokes an instant shift of positive 4.2 2002 CAD, while the long

term trend is for the expenditures to grow at a lower rate of 0.6 2002 CAD per year. The corresponding results for a second-generation tenancy rent control regime is an instantaneous effect of negative 2.2 2002 CAD and a lower growth trend of 1.4 2002 CAD per year. This is illustrated conceptually below:

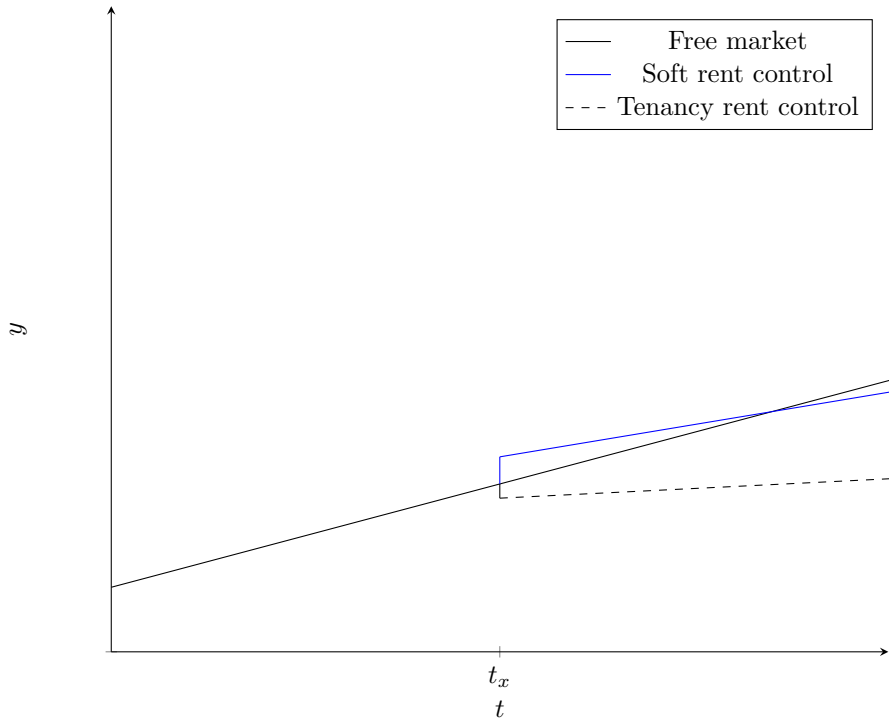


Figure 7: Impact of shifts to different rent control systems at t_x

While this illustration obviously is oversimplified, the results suggest shocks at the implementation of rent control followed by a long-term lower maintenance path. However, a large problem is that although the shock coefficients are statistically significant, the long-term effects are dictated by the rent control dummies, who are insignificant. While the qualitative output is intuitive, the value of these coefficients as measurements of magnitude are very limited and they should be interpreted with care. Note for instance that the effect of rent control with a long time horizon can for rent control system k be characterized by

$$\lim_{t\to\infty} \%C_k = \frac{\lambda + \beta_k}{\lambda}, \tag{45}$$

which would mean that in the very long run, soft rent control regimes have maintenance expenditures equal to 63 percent of the free market maintenance, with the corresponding figure for tenancy rent control being 16%. I deem these

figures unreasonable and there is thus reason to suspect that the model is ill-specified. Since these figures further depend on β_k, whose estimated coefficients turned out insignificant, there is all the reason to regard these figures with a lot of care. However, it could be the case that while ill-suited for long-term analysis of maintenance paths, the figures hold in the short run where the percentage changes aren't that sharp and still depend on the short-term shocks from the implementation.

5.3 Comparison to theoretical model

Already in equations (25) through (27), there is an obvious problem when comparing to the data. In the free market steady state, the quality, co-state and maintenance levels are time-independent. In the rent control model, there is time-dependence but no trend of continuously increasing in the steady state cycle. This can be contrasted with the regression results as well as the overarching trend: maintenance per capita is steadily increasing with time. There is a deterministic trend forcing expenditures upwards, and that trend perseveres even when subjected to control variables. As such, there is reason to question the validity of the model in the chosen setting. The implication is that either the system is not in the steady state at all during the chosen time frame, there are covariates missing from the equations, or the system is in a steady state during certain periods, but the static environment criterion is violated. A likely answer to this conundrum is that all three remedies are true to some extent.

If however the deterministic trend is taken as given, there are other takeaways of interest. Akin to the theoretical model, while the long term maintenance expenditures always will be lower under rent control regimes, the optimal choices just at the the time of implementation need not be to decrease maintenance. While I again hold little faith in the long term coefficients, the short term shocks turn out significant and of varying signs depending on which regime is implemented. While the model predicts short-term increases in maintenance expenditures going from free market to tenancy rent control, these are not present there but only when going to soft rent control. I would naturally be more confident in the model had the sign been positive for both, but the qualitative implication that lowering maintenance expenditures isn't always optimal in the short run when rent control is implemented finds some support here. The fact that both of the signs aren't positive might be a result of some misspecification, but could also possibly be a result of the time factor's interference, as discussed in the previous paragraph.

All in all, I find ambiguity with regards to how the model and the data fit together. The reasons for, and implications of, theses results will be further discussed in the coming sections.

6 Discussion

6.1 Policy

While the data output isn't fully convincing quantitatively, I deem the qualitative output to be in line with both the used model and the prevailing current research: all else equal, rent control has adverse effects on the level of property maintenance. Note that this relationship alone does not imply that rent control is good or bad as a concept as it's only a small part of the economic effect, but it can certainly be used as an argument for rent control having unintended negative effects. My interpretation in terms of policy is thus the following: given that you have no rent control, maintenance is taken care of through market forces, but given that you want rent control, there are arguments to be made for artificially increasing maintenance levels through other means.

This sounds more drastic than it actually is, and is commonplace in a large number of economies. By artificial increases, I refer to governmental interventions that increase maintenance levels without use of market forces per se. This includes, but is not limited to, laws articulating the responsibilities of a landlord without regards to the pricing level of the property. For instance, there are usually laws with regards to access adequate plumbing, which I deem a quality aspect. While it plausibly is the case that higher-priced units have better access to plumbing, a tenant in a low-quality unit can often force their landlord to maintain the plumbing, and if they refuse, involve the authorities. Plumbing is just an example: the point I'm making is that landlords are not free to let the quality deteriorate freely. These laws would in theory be unnecessary in a free market characterized by perfect competition as all maintenance responsibilities would be internalized in the price mechanism. I however deem them influential in rent control environment. While they protect the properties, and as such the national property stock, from deteriorating at too high a rate, they bring with them another problem in further losses of producer surplus. Not only can't the landlords under rent control set the market rate for their apartments, they can't choose the optimal maintenance path given the situation. In welfare terms, if rent control constitutes a transfer of surplus from producers to consumers, lowering the maintenance path is an attempt at recouping some of that surplus for the producers, which is then blocked by further governmental interventions. This loss for the producers needs to be contrasted with the societal gain from not having the property stock depreciate too fast, which calls for further empirical work.

As Arnott and Schevyakova (2014) point out, a remedy to the maintenance path being lower under rent control would be the formulation of a complete contract with subsequent enforcement. Theoretically, if a landlord and a future tenant could in the leasing contract agree on exactly what and when maintenance work is to be carried out, there would be no adverse effects of rent control on maintenance. This due to that the model, as well as the real-life examples used

par Prince Edward Island, allow for free negotiations with regards to the nominal rent. A landlord and tenant could then agree on a maintenance path which in theory would be the same as in a free market, adjusting the nominal rent such that all costs are internalized. There are however problems with this in that (1) a complete contract is impossible and/or expensive to draft, (2) it requires perfect information of all rent increases and maintenance needs during the tenancy and (3) it requires functioning enforcement mechanisms for it to work. For (1), it is nothing new in that a complete contract to a large extent is an abstraction as it is impossible to cover all possible outcomes. It further places economic costs on landlord and tenant alike in that a complete contract would require a large amount of juridical expertise, which possibly would have to be outsourced to a third party. Coupling the initial hardships with (2) imperfect information of exogenous parameters during the tenancy further hurts the chances for a reasonable contract. While rent increase limits are often proclaimed a year or so in advance, a large share of contracts are signed on a long-term basis and a theoretical nominal rent internalizing future parameters now miss said parameters. While most increases are tied to CPI and the central banks can calculate reasonable predictions in the short run, they are shaky at best in the long run. Anecdotal evidence for this is that inflation while writing this is very high in the U.S. as an effect on covid-19, a completely unexpected exogenous shock. As such, any rent control systems tied to American CPI would allow for rent increases differing from predictions, and thus a theoretical nominal rent set through CPI modelling would have been wrong.

Expanding on (2), maintenance is just as inflation by nature hard to predict. While you as a landlord to an extent can quantify the quality of a property's inventory and model maintenance accordingly, those predictions will either suffer from uncertainties or be costly. Again using plumbing as an example, you could as a landlord hire a plumber to come check the pipes once a year. This would be costly, but you would get a clear image of the quality of the property's pipes and model the needed plumbing maintenance with high accuracy. You could on the other hand do plumbing maintenance at an ad hoc basis, which, while eliminating the costs for doing inventory, lead to very volatile models for maintenance costs as the current quality isn't observable. Simply put, you can pay to know when a pipe will burst and gain from the situation's predictability, or just let the pipe burst at any time and just pay up. In either case, there are costs incurred and the inaccuracy would likely hurt the parties' possibility to arrive at a correct nominal rent. It would furthermore accentuate the prevalence of asymmetric information in the relation between landlord and tenant. I deem it likely that on a general level, landlords know more about property maintenance than tenants since they take care of properties for a living. The implication is then that even when presented with identical figures from the plumber with regards to the quality of the piping, it is likely that the landlord has an information advantage. This is not beneficial at all since the tenant either has to hire an expert or face the risk of the landlord exaggerating the quality of the piping and bargaining a higher rent, and either one of those options imply a

cost for the tenant. As with Akerlof's peaches and lemons (1970), this would lead to a situation where an unaided tenant always assumes that the landlord is overplaying the quality of unobservable aspects of quality, introducing adverse selection. While the solution is obvious in that an expert surveys information to the parties that both can understand, it is a cost. Note that this phenomenon is in the nature of unobservable quality and as such is present even without rent control. The point is here solely being made to reinforce my argument for the complete contract to not be a viable solution.

Finally, given that a maintenance path has been agreed on, it is useless without (3) an enforcement mechanism. If the parties for instance agree on the free market maintenance path, a landlord without enforcement pressure would logically ignore the agreement and instead go for the rent control maintenance path to maximize their profits. The obvious solution is making use of law enforcement, such that authorities become involved if the landlord doesn't fulfill their part of the contract. This of course suffers from (1) the incompleteness of the contract, but even if all gaps have been filled, there is a cost incurred on the tenant as they have to bring the case to court. Even if the costs are recouped at a sentence, it might be the case for tenants to discount that future reimbursement at a high level. Especially considering that a lot of tenants are at the lower end of the income spectrum, there might be liquidity restraints as to their possibility and will to pursue a case. This is further accentuated if the contract is complex, which it has to be ad absurdum if it is to be complete, as it then becomes difficult for a tenant to fully know their rights. A possible remedy for this is sufficiently harsh monetary penalties for irresponsible landlords such that even with liquidity constraints and a high level of future discounting, a tenant would pursue the case anyway. I view this measure with scepticism as there is a risk of creating a lot of rent-seeking activities if the rewards are high and the contracts are incomplete, which would reduce welfare until the contracts become complete, which, again, is possibly never. A second remedy would be to shift the responsibility of pursuing a case away from the individual tenant. A common case is having tenant organizations pursing cases on behalf of tenants, but there are also instances of governmental agencies for consumers representing individuals against landlords. That way, a tenant may pursue a case without having to spend a lot of time and money. While tenant organizations usually charge a nominal fee per time period, the costs are likely minuscule compared to legal fees. On the other hand, seeking aid from a governmental agency might be free, but it further involves the government in the bargaining process, which might not be desirable. All in all, I however evaluate the process of organizations speaking for the tenant in legal maintenance matters against the landlord to be a welfare-increasing system, no matter if it is done privately or through governmental channels. There is possibly even a case here to be made for subsidizing memberships in tenant organizations, if for instance membership increases welfare but is purchased at a level lower than the social optimum.

One could also think of a remedy to the enforcement problem in letting reputation serve as a punishment mechanism. Theoretically, if a landlord systematically lies about the maintenance they will perform, they will get a worse reputation, fewer customers and thus lower profits. This, while theoretically reasonable, is not a realistic way to look at the market for rental apartments. When vacancy rates are low, the market doesn't to any reasonable extent let prospective tenants pick and choose between landlords: they should be happy that they simply get an apartment. Given that the tenant however is free to choose whatever landlord they wish, I deem it unrealistic for their choice to be substantially impacted by the reputation of the landlord with regards to maintenance, as I would suspect factors such as rent, location, size and current quality dominate when making housing choices.

A further policy worth looking at, given that rent control is imposed, is the allowance of cost pass-through systems, where the landlord is allowed to raise rents given that the increase is tied to declared maintenance costs. This has the theoretical upside that a landlord now has a rationale to increase maintenance levels even during the early period of a tenancy, and as such the quality won't deteriorate too fast. It however also brings with it the possibility of overmaintenance. Since the landlord can maintain to raise rent, a predatory landlord could now theoretically use maintenance as an excuse to raise rent, when in fact the motivation behind the rent increase is something else such as increased purchasing power with the tenant. As such, a cost pass-through system with lacking administrative capacities could render the rent control system inefficient as a whole. There would thus have to be a governmental body responsible for either approving the raises beforehand, or alternatively serve as a judicial body handling appeals from tenants facing potentially unfair raises. Both alternatives have drawbacks. If a governmental body has to approve all raises, there will be potentially be a large cost to the taxpayers as it would require a lot of administrative work. If on the other hand the body only handles appeals, this would be relatively worse for the tenants facing time, knowledge and liquidity constraints, akin to the previous reasoning about contract appeals. All in all, I think the policy absolutely is worth consideration, but a government adopting the policy should move carefully as to not create unfair advantages or burden taxpayers excessively.

6.2 Limitations

An obvious limitation of the model used, as implied in the data, is the assumption of static parameters. One could very well imagine the parameters changing over time, especially when considering such a long time period as I am. This is particularly clear with parameters that have intuitive qualitative interpretations. For instance ρ, denoting a form of construction cost, is likely to have changed over the time period due to technological advances, even after adjusting for inflation. Similar reasoning can be made with regards to the pricing function P or the depreciation function g. Is it reasonable for the relation

between quality and nominal rent levels to stay constant over fifty or so years? Intuitively, no. As such, a fuller model to be used for longer time spans should let parameters change over time, e.g. denoting construction costs with ρ_t. This of course complicates all subsequent analysis, perhaps even to the level where the model loses its purpose. It is important to remember that models are tools to simplify the complicated world in which we live, and if it fails to provide any simplification, the rationale behind using a model vanishes. An alternative approach to this limitation is the insight that this might be too long of a time period for this model to be useful, and as such I should have chosen another model or a smaller time frame, perhaps instead expanding the cross-sectional part of the panel by including more jurisdictions.

The rent control model further is limited in that it assumes L to be exogenously given and known in advance by both the landlord and the tenant, which isn't typically the case in real life. A significant share of tenancies are in reality constructed in such a way that the tenant is allowed to stay until further notice, that is that there is no fixed terminal date for the lease. This of course further complicates the contract reasoning above, but it also has modelling implications as it is hard for a landlord to optimize their maintenance expenditures in such a way that they reach the perfect quality at exactly the terminal time if they do not know the terminal time beforehand. Intuitively, the act of not knowing the terminal time should make the landlord postpone maintenance even further if L is unknown. This problem is mitigated in part by most jurisdictions having a period of notice for landlords and tenants alike. Given that a tenant has to proclaim their moving out and thus the terminal time of the contract, the landlord is given some respite during that period when they can increase maintenance expenditures, albeit not as optimized as if they knew the terminal time during the entire tenancy. This is further a problem if the landlord during a tenancy can affect L. One could easily imagine a scenario where a landlord does little to no maintenance in order for quality to drop, which increases incentives for the tenant to move out, such that the landlord then during the period of notice can do a lot of maintenance to boost quality and subsequent new nominal price for the next tenant. In an extreme case, one could even imagine a particularly predatory landlord to remove or worsen residential services that are not contractually binding in order for the tenant to move. This act could, while not covered by the model, even be characterized by negative maintenance expenditures such that the quality of living depreciates at a faster rate than if maintenance was put to zero.

I furthermore feel on a general level that the empirical part of the paper is lacking in execution. While the possibility of unit roots forced my hand with regards to using the first difference dependent estimator, it severely hurt the statistical power of the setup. Since a difference transformation necessarily transforms step dummies into pulse dummies, it brought with it a lower level of variance in the independent variable of interest, with just a small number of ones in a giant spreadsheet of zeros. Coupled with my inability to explain the

deterministic trend of increasing maintenance expenditure, I do not feel that confident about the internal econometric validity. As is, the deterministic time trend, portrayed by the constant in a first difference regression, serves as a proxy for covariates that are unaccounted for. It is either the case that maintenance per capita is in fact increasing over time for some reason unknown to me, or the data collection is getting better over time. I deem the first one to be the most likely as I had hoped that the urbanization covariate would account for better measurement. It is neither the case that the expenditures are rising because a larger share of tenants live in these contracts: the trend is identical for owner-occupied housing. A possible explanatory factor could be an aging housing stock if, at odds with the theoretical model, there is a positive relation between time since construction and maintenance needed. This could possibly be included as e.g. some variable of average house age in a province a given year, but there are unfortunately data availability problems in that regard.

That being said, I deem that given that there is a deterministic time trend, it makes sense for rent control to have interactions with said trend, as modelled. The alternative would be a reasoning in limits where in the long run, the maintenance path under rent control converges to the free market counterfactual, which intuitively as well as theoretically should not be the case. It is as such disappointing that I got insignificant regression coefficients for the constant changes in table 5. While I again feel that the signs as well as their relative ordering make sense, the standard errors are large enough that I would discourage any reader to draw any quantitative conclusions from that regression. The low statistical power, again, is largely a direct result from the first difference approach. An alternative angle to this problem could be to move away from the panel approach and instead test each time series for structural breaks at the times of policy changes. While it certainly has its merits to treat a panel as such, having ten separate time series might be easier to model properly. It would however result in a number of separate coefficients who would only be valid within the province, as opposed to my statistically weak but all-encompassing panel approach resulting in just a few, easily interpreted coefficients.

7 Conclusion

In this paper, I have tried to analyse the adverse effects of rent control regimes on property maintenance using both a theoretical and an empirical framework. All else equal, both the theoretical model and the data suggest that rent control leads to a lower long term maintenance level than in a free market. That implies, assuming that the free market level is efficient, that rent control brings with it welfare losses as properties depreciate at a superficially high level. Coupled with generally low vacancy rates in geographical jurisdictions with rent control, this poses a problem: not only are there not enough units supplied, but those supplied are losing quality at too fast a rate. This can certainly be used to critique the policy of rent control, but it is important to remember that

property maintenance is but a single cog in the vast macroeconomic machinery. My own policy recommendation, as discussed in the previous section, is for governments who do impose rent control to govern property maintenance through other control systems such as enforcing laws or encouraging bargaining processes. While all maintenance costs are skewed towards the landlord in the classic rent control setting, a way to circumvent this would be to allow cost pass-through exemptions to some extent, which is not uncommon. That way maintenance can be undertaken, but it also brings with it a problem that a landlord can then choose too high of a maintenance level in order to be allowed to raise rents.

While I have little faith in my quantitative results, I deem the qualitative and theoretical results to be perfectly plausible. The optimal maintenance undertaken by a landlord depends on how he can recoup those costs through higher rents. In a free market setting, rent increases can theoretically occur on a continuous basis, and as such it makes perfect sense for the system to approach a steady state where maintenance stays on a stable level. If, as the data suggests, maintenance expenditures are increasing over time, it would then translate to a steady state path where maintenance is for instance linearly dependent on time. In a stark contrast, the landlord in a vacancy decontrol setting can only increase his rents at discrete time periods. It is as such natural that his optimal maintenance expenditures are best characterized by a sawtooth function such that maintenance is low at the start off a tenancy and high at the end to the discretely drop when a new tenant signs a contract. Such a function would however be impossible to see using aggregate data as I am, as the result when summing over an entire population of landlords would only be the lower average position. Should we however have access to individual units and their corresponding expenses, the function should be visible.

Finally, I feel that there is more, and better executed, empirical work to be done on this matter. While I partly fail to show the theoretical model's full power, a more in-depth model calibration could potentially improve the model's explaining power. Parameters as well as functional forms are decided on an "educated guesses"-basis, but they could theoretically be confirmed and/or altered by a thorough empirical study. For instance pricing functions, construction costs and quality depreciation should not be impossible to model properly through data, perhaps even leading to new functional forms and new qualitative conclusions.

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A Appendix

A.1 Solution to maintenance path

The problem is as follows given exogenous L, q_s, q_L:

$$\max_m \int_0^L -e^{-ru} m du, \tag{46}$$

subject to:

$$\dot{q} = g(q, m) = -Bq + Cm^{\beta} \tag{47}$$

$$q(0) = q_s \tag{48}$$

$$q(L) = q_L \tag{49}$$

Current-valued Hamiltonian:

$$\mathcal{H} = -m + \phi(-Bq + Cm\beta) \tag{50}$$

Pontryagin's maximum principle:

$$\frac{\partial \mathcal{H}}{\partial m} = -1 + C\phi\beta m^{\beta-1} = 0 \implies m = \left(\frac{1}{C\phi\beta}\right)^{1/\beta-1} \tag{51}$$

We further need:

$$\dot{\phi} - r\phi = \frac{\partial \mathcal{H}}{\partial q} = B\phi \tag{52}$$

We now have two motions:

$$\dot{\phi} = (B + r)\phi \tag{53}$$

$$\dot{q} = -Bq + C\left(\frac{1}{C\phi\beta}\right)^{\beta/\beta-1} \tag{54}$$

While the quality function is nonlinear in ϕ, it is easy to verify that the following equations hold:

$$\phi(t) = c_1 e^{t(r+B)} \tag{55}$$

$$q(t) = c_2 e^{-Bt} + \frac{1-\beta}{B+\beta r} C^{1/1-\beta} \left(\beta c_1 e^{t(r+B)}\right)^{\beta/1-\beta} \tag{56}$$

To simplify, I define:

$$\sigma \equiv \frac{\beta}{1-\beta} \tag{57}$$

$$\Omega \equiv \frac{1-\beta}{B+\beta r} C^{1/1-\beta} \tag{58}$$

Note that both σ and Ω are positive by definition. Using conditions for $q(0)$ and $q(L)$:

$$q(0) = c_2 + \Omega\left(\beta c_1\right)^{\sigma} = q_s \tag{59}$$

$$q(L) = c_2 e^{-BL} + \Omega\Big(\beta c_1 e^{L(r+B)}\Big)^{\sigma} = q_L \tag{60}$$

This is now a simple equation system with two unknowns, c_1 and c_2. The solution is given by:

$$c_1 = \left(\frac{q_L - e^{-BL} q_s}{\Omega\beta^{\sigma}\Big[e^{\sigma L(r+B)} - e^{-BL}\Big]}\right)^{1/\sigma} \tag{61}$$

$$c_2 = q_s - \frac{q_L - e^{-BL} q_s}{e^{\sigma L(r+B)} - e^{-BL}} \tag{62}$$

If we again simplify by letting:

$$\omega \equiv \frac{q_L - e^{-BL} q_s}{e^{\sigma L(r+B)} - e^{-BL}}, \tag{63}$$

the solutions to the state and co-state equations are:

$$q(t) = e^{t(r+B)}(q_s - \omega) + e^{\sigma t(r+B)}\omega \tag{64}$$

and

$$\phi(t) = \frac{e^{t(r+B)}}{\beta}\left[\frac{\omega}{\Omega}\right]^{1/\sigma}, \tag{65}$$

which translates to the optimal maintenance path:

$$m(t) = \left(C^{1/\beta-1} e^{\frac{t}{\beta-1}(r+B)}\left[\frac{\omega}{\Omega}\right]^{1/\beta}\right)^{-1}, \tag{66}$$

or in terms of the original parameters:

$$m(t) = \left(C^{1/\beta-1} e^{\frac{t}{\beta-1}(r+B)}\Big[\frac{(q_L - e^{-BL})(B+\beta r)}{(e^{\sigma L(r+B)} - e^{-BL})(1-\beta)C^{1/1-\beta}}\Big]^{1/\beta}\right)^{-1} \tag{67}$$

It might be of interest to see how maintenance changes with time:

$$\dot{m} = -\left(C^{1/\beta-1} e^{\frac{t}{\beta-1}(r+B)}\left[\frac{\omega}{\Omega}\right]^{1/\beta}\right)^{-2} C^{1/\beta-1} e^{\frac{t}{\beta-1}(r+B)}\left[\frac{\omega}{\Omega}\right]^{1/\beta}\frac{r+B}{\beta-1} \tag{68}$$

Since $\beta \in (0,1)$, this expression is positive as long as:

$$\left[\frac{\omega}{\Omega}\right]^{1/\beta} \tag{69}$$

evaluates to a positive, real number. Ω is always positive, whereas the sign of ω depends on the given values of q_L, q_s and L.

A.1.1 Steady state cycle condition

As shown above, maintenance increases with time if ω evaluates to a positive number. Since $q_s = q_L = q^*$ in a steady state cycle, it can be rewritten as:

$$\omega = \frac{q^*(1 - e^{-BL})}{e^{\sigma L(r+B)} - e^{-BL}} \tag{70}$$

Since $q^* \geq 0$ and $(1 - e^{-BL} \geq 0$, it suffices to show that

$$e^{\sigma L(r+B)} - e^{-BL} \geq 0 \tag{71}$$

in order for maintenance to increase over a tenancy.

$$e^{\sigma L(r+B)} \geq e^{-BL} \tag{72}$$

$$\frac{e^{\sigma L(r+B)}}{e^{-BL}} \geq 1 \tag{73}$$

$$e^{\sigma Lr + \sigma LB + BL} \geq 1 \tag{74}$$

Since $e^0 = 1$, this always holds if:

$$\sigma Lr + \sigma LB + BL \geq 0 \tag{75}$$

and since all entries are positive, maintenance is increasing over the time period.

A.2 Supplemental figures

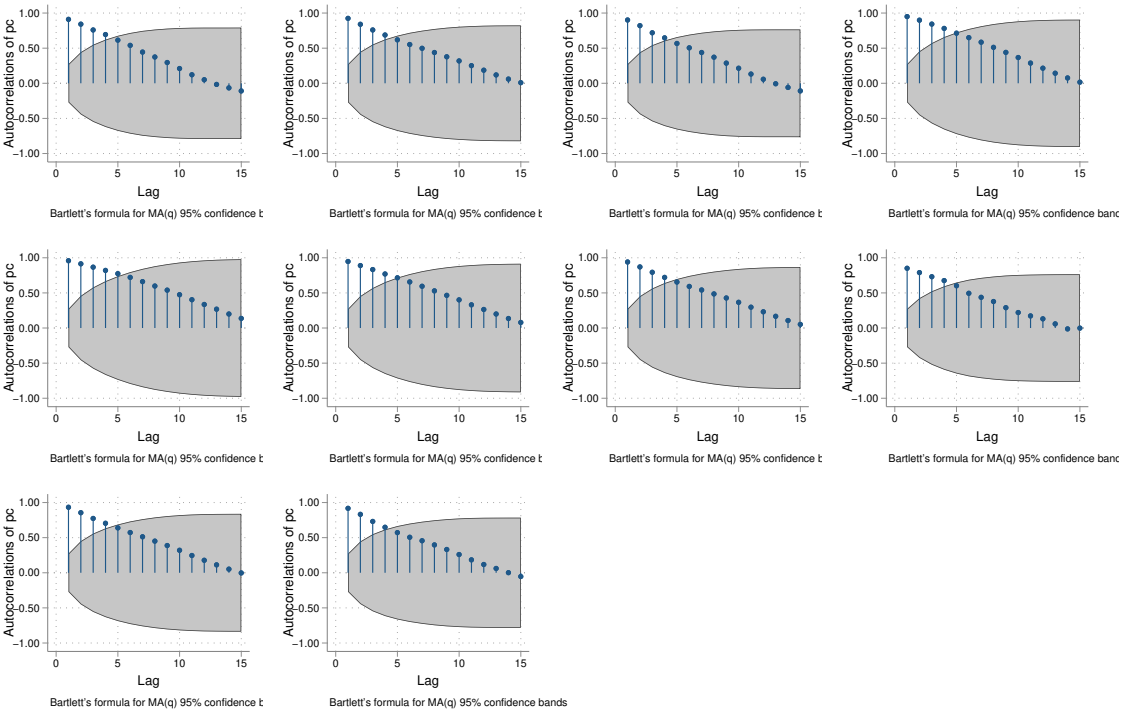


Figure A1: Autocorrelation for the ten provinces

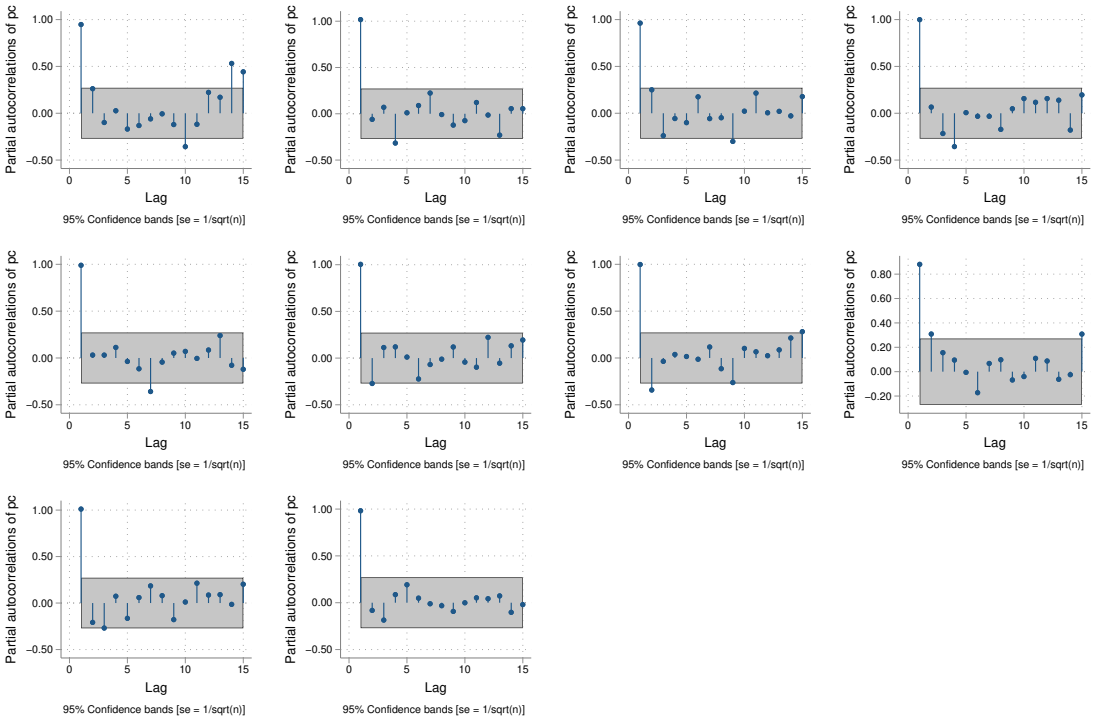


Figure A2: Partial autocorrelation for the ten provinces

A.3 Supplemental tables

Province	Rent control
Alberta	2,1976-1980
British Columbia	2,1974-1984, 1,1992-2002, 2,2002-
Manitoba	2,1976-1980, 2,1982-
New Brunswick	0,Unregulated
Newfoundland and Labrador	0,Unregulated
Nova Scotia	2,1975-1993
Ontario	2,1975-1992, 1,1992-2017, 2,2017-
Prince Edward Island	3,1968-
Québec	0,Unregulated
Saskatchewan	0,Unregulated

Table A1: Categorical treatment of rent control systems

Description	Function
Pricing function	$P(q) = Aq^{\alpha}$ with $\alpha \in (0,1)$ and $A \geq 0$
Depreciation function	$g(q,m) = -Bq + Cm^{\beta}$ with $B, C \geq 0$ and $\beta \in (0,1)$

Table A2: Assumed functional forms