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Economic impact of a supply change in mass transit in urban areas: A Canadian example

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ABSTRACT

This paper aims at estimating the economic impact of a supply change in the bus transit service in a Canadian city of medium size. By using a quasi-experiment approach and a difference-in-differences (DID) estimator, it evaluates the impact of the introduction of a rapid bus transit (RBT) in Quebec City (Canada) through a spatio-temporal analysis of house price variations. The hedonic price model shows that the new service generates an increase in house price ranging from 6.9% to 2.9%, for those properties located close to the service corridor where the population is quite dense and where the service was offered initially. Using sales transaction data and municipal assessment records from 1997, the effect on price is translated into an economic impact for the whole region. The paper shows that the improvement in public transit supply generates, for Quebec City, a significant fiscal impact estimated to $6 M and a plus-value for properties owners close to $35 M over 12 years. Finally, the implications of this kind of analysis for urban planning and development are discussed.

0. Introduction

Public transportation (PT) plays a social role in the urban environment: it improves access to workplaces and service infrastructures, and at the same time reduces travel expenses. Moreover, within the context of reducing traffic congestion and greenhouse gas emissions, many people believe that public transportation must play a major role as an alternative to the private car. This being said, the funding of equipment and public infrastructures gives rise to debate among users and non-users to determine just who must bear the costs for these services. PT infrastructure costs are being financed by the various levels of government while most of the operating costs are being shared at the local level through property taxes by all and through ticket sales by users. Self-funding rarely occurs, especially in mid-sized cities where the modal share of PT is generally low.

The tricky problem of financing PT is evident in a majority of cities. However, there is a connection between the presence of a PT service close to a residence (or to a workplace or business) and the effect on the market price, or rent, of houses. Indeed, in a free and competitive market, such an externality should be capitalized, at least partially, in the market value. The main goal of this paper is to estimate the economic impact that results for both affected homeowners and for municipalities, by modifying the local bus network through the addition of several rapid bus transit (RBT) corridors. In a "smart-growth", "transit-oriented development" or "livable communities" context, we assume that part of the service deployment and

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operation can be financed by the consumer's willingness-to-pay (WTP) for proximity to the RBT line, resulting in a positive externality that is internalized in property values.

This research is divided into two sections: the first seeks to identify the marginal impact that improving a bus service has on the selling price of single-unit residential homes, while the second uses the results to evaluate the effect of house price variations on the municipality's tax revenues, in addition to evaluating capital gains for owners of those houses affected by service enhancement. For many, the question of *profitability* or *benefit* derived from the service becomes an important decisional criterion in light of increasing public interest for an alternative to the overwhelming role of the private car as the main transportation mode and a potential solution to increase population density in the region.

This paper addresses the improvement of the PT supply as an exogenous transformation for the region and in the perspective of a quasi-experiment. This provides the advantage of eliminating the differences among residences (property specific) and locations (impacts of other neighbourhood factors and location rents), which are deemed fixed in time. It is a good evaluation tool to measure policy and service changes in an urban setting.

The paper comprises five sections. Section 1 introduces the current literature pertaining to measuring the impact of the PT supply on the (re)sale price of homes, distinguishing between the effect of rail and bus services. Section 2 presents the methodology and method needed to estimate the price impact. Section 3 presents the data used in this research, conducted in Quebec City, Canada. It also provides an overview of the PT transformations that have occurred in 1992 and 1995 with the introduction of a RBT service, along with the changes in modal shares from 1991 to 2006. Section 4 displays the results and calculates the economic impact of the PT supply improvement for municipalities and home owners, in addition to discussing the importance of the findings in a global approach to funding PT infrastructures. The paper ends with a brief conclusion and a summary of the findings.

1. Literature review

In theory, a residence is a complex good and its sale price depends on the specific combination of its characteristics (Rosen, 1974), including externality effects and location rent (Dubin, 1998; Strange, 1992; Can, 1992; Yinger et al., 1987; Shefer, 1986; Hickman et al., 1984; Krantz et al., 1982). PT influences location rent by: (1) improving access to services; (2) creating a nuisance due to noise and increased traffic.

Although some authors, like Garrett (2004), have attempted to isolate the two opposite effects by using distinct definitions to distinguish them, the nuisance impacts on rents are slight. Normally, only accessibility, measured by the distance to the nearest station, is valued, while service nuisance, expressed by the distance to the service corridor, is not significant. However, Chen et al. (1997) found that the nuisance effect can sometimes be significant. Their study highlights the fact that the negative impact reaches its maximum level at 215 m and then diminishes, while the rental scale distribution is similar to an asymmetric distribution concentrated near the service point.

To date, most studies on location rent associated with PT refer to rail transport networks and have assessed the net price impact, expressed as the difference between accessibility and nuisance effects. In order to measure the relative location of houses, most studies use the Euclidian distance to the nearest station, a quite simple measure. However, Ryan (1999) argues that walking time is more appropriate, as it highlights clear micro-patterns that are more in line with theoretical expectations.

According to the most pessimistic scenario, the estimated impact is null (Landis et al., 2004; Gatzlaff and Smith, 1993) due to a full compensation of both externalities. The majority of the studies report positive impacts, with the amplitude and interpretation varying across municipalities (Table 1). Several arguments are put forward to explain these local discrepancies. One theory rests on change expectations. Several authors believe that the introduction of a major infrastructure, especially a rail network, requires a delay during which stakeholders speculatively internalize the effect even before the service becomes operational (McMillen and McDonald, 2004; Knaap et al., 2001; McDonald and Osuji, 1995). Yiu and Wong (2005) report the same type of frenzy in the market during the construction of a road tunnel in Hong Kong.

Other authors stress the fact that the effect can vary according to the characteristics of stations and their location. Voith (1991) notes that the effect of a commuter rail system to Philadelphia is stronger for residences located in New Jersey as opposed to Pennsylvania. Some point out that the effect may vary according to the city or district studied (Celik and Yankaya, 2006; Lewis-Workman and Brod, 1997). Ryan (2005) demonstrates that the effects of a rail network's proximity on industry vary from city to city. Those industries located near the centre tend to pay more to relocate farther from transportation infrastructures, while those located in the outskirts demonstrate the opposite behaviour. For the residential market, Hess and Almeida (2007) demonstrate that, for the city of Buffalo, the rent premium for proximity to a station varies from 2% to 5% of value, depending on the quality of service. The question of service quality is also raised by Landis et al. (2004). Other studies show that the location premium varies according to the degree to which the service is used (Cervero and Duncan, 2004) and the type of clientele (Nelson, 2004; Bowes and Ihlanfeldt, 2001).

Another point raised to explain the variations in the estimated location rent revenue pertains to substitution effects. The potential of substituting PT for some other transportation mode, such as the automobile, is an important issue. Gatzlaff and Smith (1993) cite low substitutability among modes to explain the absence of significant price difference between homes located near a subway station in Miami, in comparison to other homes in the city. Voith (1993) and Debrezion et al. (2007) show that proximity to highways also plays a role in the evaluation of rail proximity. Lastly, the possibility of using PT for multimodal travel also has an influence on prices (Bowes and Ihlanfeldt, 2001; So et al., 1997).

Table 1
Synthesis of estimated impacts in literature – rail.

Authors	City	Impact
Dewees (1976)	Toronto	↑ price of 2370 $
Bajic (1983)	Toronto	↑ price of 2237 $
Voith (1991)	Philadelphia	↑ price of 6707 $ in New Jersey
		↑ price of 3437 $ in Pennsylvania
Gatzlaff and Smith (1993)	Miami	→ No significant effect
Landis et al. (2004)	San Fransisco	↓ price of 2.29–1.96 $ by meter of distance
	San Jose	→ No significant effect
	San Diego	→ No significant effect
	Sacramento	→ No significant effect
McDonald and Osuji (1995)	Chicago	↑ price of 17% within 800 m
Benjamin and Sirmans (1996)	Washington DC	↓ price of 2.5% within 160 m
Lewis-Workman and Brod (1997)	San Fransisco	↓ price of 51.77 $ by metre of distance
	New-York	↓ price of 75.43 $ by metre of distance
	Portland	↓ price of 2.49 $ by metre of distance
Chen et al. (1997)	Portland	↓ price of 32.20 $ by meter distance
So et al. (1997)	Hong-Kong	↑ price of 3.2% if under 10 min walk
Haider and Miller (2000)	Toronto	↑ price of 4000 $ if within 1 km of a station
Baum-Snow and Kahn (2000)	US Cities	↑ price of 4972 $ for a diminishing of 2 km
Cervero and Duncan (2004)	Santa Clara	↑ price (commercial) by 43 $/m^2 within 400 m
Knaap et al. (2001)	Washington DC.	↑ price (land) of 36% within 800 m
		↑ price (land) of 9% within 1.6 km
Weinstein and Clower (2003)	Dallas	↑ price higher by 39% within 400 m
		↑ price (offices) higher by 53% within 400 m
McMillen and McDonald (2004)	Chicago	↑ mean price of 6000 $ within 200 m
Garrett (2004)	St-Louis	↑ price of 139.92 $ by meter from a distance of 1.46 km
Celik and Yankaya (2006)	Izmir, Turkey	↓ price of 4.76 $ by additional metre of distance
Hess and Almeida (2007)	Buffalo	↑ price of 1300 $ to 3000 $

Very few studies focus on the impact of the improvement of a bus service, and for those that have been published, the conclusions vary widely. So et al. (1997) address this issue in their study on Hong Kong. In order to measure the impact of PT on housing prices, they measure the distance of a home to the nearest station (bus and/or minibus). They also use dummy variables to identify those homes located more than a 10-min walk from a stop. Although results show that proximity to the bus route does not have a significant influence on housing prices, access to minibus is seen to have a significant positive effect. Cao and Hough (2007) show that, for the city of Fargo in North Dakota, the proximity to a station has a negative effect on prices for homes within less than 200 m (an eighth of a mile), while no significant impact is recorded beyond that distance. The authors argue that high dependency on the automobile makes a substitution between the two modes of transportation improbable, especially in a small-sized urban centre. An Australian study (Real Estate Institute of Queensland, 2001) shows that the median price increase for houses located along a bus route in Brisbane's suburbs is clearly higher (10.1%) than that found in the remaining region (3%), thereby suggesting that a bus service may exert a positive effect on house prices in highly urbanized areas.

More recently, Levinson et al. (2002) have proposed a paper to characterised and described rapid bus transit (RBT) services as a PT mode. Few studies have focused on the effect of introducing new RBT services. Rodriguez and Targa (2004) estimate, for Bogotá, Columbia, that the rental prices for residences located near a station increase by 6.8–9.3% for each 5-min reduction in walking time to the station. They also show that the effect is less important on rental dwellings than on the (re)sale price of homes. These conclusions are corroborated by a study by Munoz-Raskin (2006) focussing on the new housing market. A subsequent study in Bogotá, based on a comparison of sales price variations according to geographical location, reveals more subtle conclusions. Rodriguez and Mojica (2008) use data on single-family home sales before and after the introduction of the second phase of the RBT in order to assess the net impact of the improvement in the service supply on sales prices. They show that, for residences that had already benefited from the service following the first phase, in 2000, housing prices are higher on average by 15–20%. However, for those homes that experience a service supply increase during the second phase, in 2003, the price increase is comparable to that of the group of residences experiencing no change in the PT supply. The authors believe that this absence of effect is linked to elements of local conditions or perhaps to heterogeneous price variation mechanisms within a 1-km corridor on either side of the service route.

Using asking sale prices for residential properties, Rodriguez and Mojica (2009) develop a before-after hedonic pricing model to evaluate the impact of expansions of RBT service in Bogotá. It is the first study on RBT to use data over many years in order to measure the impact of a new PT system on prices. Using different price indices and controlling for many physical as well as environment amenities, they found a positive significant effect, varying between 7% and 14%, between RBT expansion and asking prices by sellers. However, they noted that the effect could be related to difference in sub-market real-estate fluctuations. Moreover, the authors noted that the estimate effect is not conclusive since the model is flawed by colinearity between variables, spatial autocorrelation between residuals and heterogeneity in the estimate variance.

The scarcity of RBT service impact studies on rental and sale prices supports the relevance of this research. Moreover, to insure that market premium is estimated, data on actual transaction prices is used instead of asking prices (Rodriguez and Mojica, 2009) to develop a general model framework that allows to overcome several problems related to estimating the impact of PT. Considering that RBT has received little attention while it is a convenient, flexible and affordable mass transit system, we focus on estimating its impact on housing values. Our modelling procedure also expands the analysis by transforming the effects on location rent into an economic impact, for both municipalities and home owners located within 500 m of the service corridor. Given that Quebec City is a typical example of an average-sized North American metropolitan region, it serves as an adequate study region for measuring such effects.

2. Methodology

On the one hand, the hedonic price model enables us to express the selling price of a property according to its physical and environmental attributes (Thériault et al., 2005; Boyle and Kiel, 2001). Extensive literature is available on the functional form that the relationship should adopt (Halvorsen and Pollakowski, 1981; Box and Cox, 1964) and on the attributes required to conduct a regression analysis (Sirmans and Benjamin, 1991). Most of the empirical studies applied to PT use the log-linear method (Smith and Gihring, 2006) whereby the logarithm of the house price of a residence i in time t, p_{it}, is regressed on the k characteristics of the house, X_{kit}, and a set of dummy variables for each sales quarter that allows to calculate a price index for the overall period, δ_t (Eq. (1)).

$$p_{it} = \delta_t + \sum_{k=1}^{K} \beta_k X_{kit} + e_{it} \tag{1}$$

On the other hand, the difference-in-differences estimator (DID), used extensively in labour economics (Meyer et al., 1995; Card and Krueger, 1994; Card, 1990), enables us to estimate the impact of a policy, to a date t^*, assuming that this change is exogenous to agents (Rosenzweig and Wolpin, 2000; Meyer, 1995; Campbel, 1969). This estimator compares two sets of observations, one being affected by the change while the other is not, before and after an exogenous change in environmental amenities. It requires the introduction of two new variables in the regression equation. The first (Eq. (2)) identifies those residences that are affected (M_{ij}) by this change within a given radius (j) of the service,[2] while the second (Eq. (3)) indicates the transaction dates subsequent to the change in policy or environmental amenities[3] (E_{t^*}).

$$M_{ij} = \begin{cases} 1 & \text{if house } i \text{ is located in the } j \text{ corridor radius} \\ 0 & \text{otherwise} \end{cases} \tag{2}$$

$$E_{t^*} = \begin{cases} 1 & \text{if } t \geqslant t^* \\ 0 & \text{otherwise} \end{cases} \tag{3}$$

By using these two new variables, the hedonic price model, including the DID estimator, is defined by

$$p_{it} = \delta_t + \sum_{k=1}^{K} \beta_k X_{kit} + \sum_{j=1}^{4} \psi_j M_{ij} + \sum_{j=1}^{4} \phi_j M_{ij} E_{t^*} + e_{it} \tag{4}$$

where ψ_j represents a specific location rent effect for houses located in the j radius corridor and ϕ_j represents the net impact on prices upon introducing the new RBT service within the j radius.

One way to avoid several problems relating to the functional form of price equation, the attributes to include and the use of heterogeneous data sources[4] is to choose the repeat-sales (RS) approach (sales–resales) (Bailey et al., 1963) whose estimator is based on the appreciation of properties deemed of constant quality and invariable in their physical and neighbouring characteristics. Formally, it expresses the difference between the hedonic price equation of a residence sold at time s and resold at time r (Eq. (5)).

$$p_{ir} - p_{is} = (\delta_r - \delta_s) + \sum_{k=1}^{K} \beta_k (X_{kir} - X_{kis}) + \sum_{j=1}^{4} \psi_j (M_{ij} - M_{ij}) + \sum_{j=1}^{4} \phi_j (M_{ij} E_r - M_{ij} E_s) + (e_{ir} - e_{is}) \tag{5}$$

The relationship, under given assumptions,[5] is simplified and expresses as the regression of the logarithm of the resale-to-sale price ratio on the sale date, the resale date and a vector of dummy variables identifying the residences affected by the

[2] Which represent a treatment effect group as opposed to a control effect group.

[3] By using a dichotomic definition, the model postulates that the effect is unchanged over time. The restriction can be relaxed by including interaction terms between this variable and dummy variables for years. However, this specification requires many observations for each year and each corridor, which is not the case here.

[4] This approach also allows us to work simultaneously with two databases that do not contain the same data on the characteristics of residences, as is the case for this study.

[5] The repeated sales method postulates that: (1) the characteristics of properties remain unchanged in between sales (no major renovations during ownership) and (2) the implicit prices of attributes remain unchanged over time (the marginal contribution of characteristics on price is stable), thus assuming a long-term equilibrium on the residential market.

introduction of the new RBT service. Gibbons and Machin (2008) argue that this approach offers the advantage of disregarding the differences among residences and other location factors that are deemed fixed in time, and is thus a powerful spatio-temporal analysis tool for the effect to be studied.

Assuming that the difference in error terms in Eq. (5) follows a random walk distribution, the equation can be estimated by the regular method of ordinary least squares (Eq. (5′)).

$$\Delta p_{irs} = \delta_r - \delta_s + \sum_{j=1}^{4} \phi_j M_{ij}(E_r - E_s) + \Delta e_{irs} \tag{5′}$$

where ϕ_j is the parameter that will be used to evaluate the economic impact of the new public transportation service on the municipality's tax revenue.

3. RBT service deployment, evolution of modal shares and databases

Located 250 km east of Montréal, Quebec City has a population of 516,010 in 2006 (up from 490,271 in 1991), with the surrounding metropolitan area (QMA) counting nearly 715,000 inhabitants (2006 census). In 2006, the average household income was set at \$59,030, while median earnings for workers reached \$38,851. One of the characteristics of the QMA, which extends over 3276 km^2, relates to its highway network, which is one of the most extensive in North America on a per capita basis, providing ease of access and reducing traffic congestion. As a consequence, the PT system is marginalized and made less competitive against the automobile; this, in turn, affects its profitability and, potentially, its implicit valuation by citizens when it comes to choosing a location.

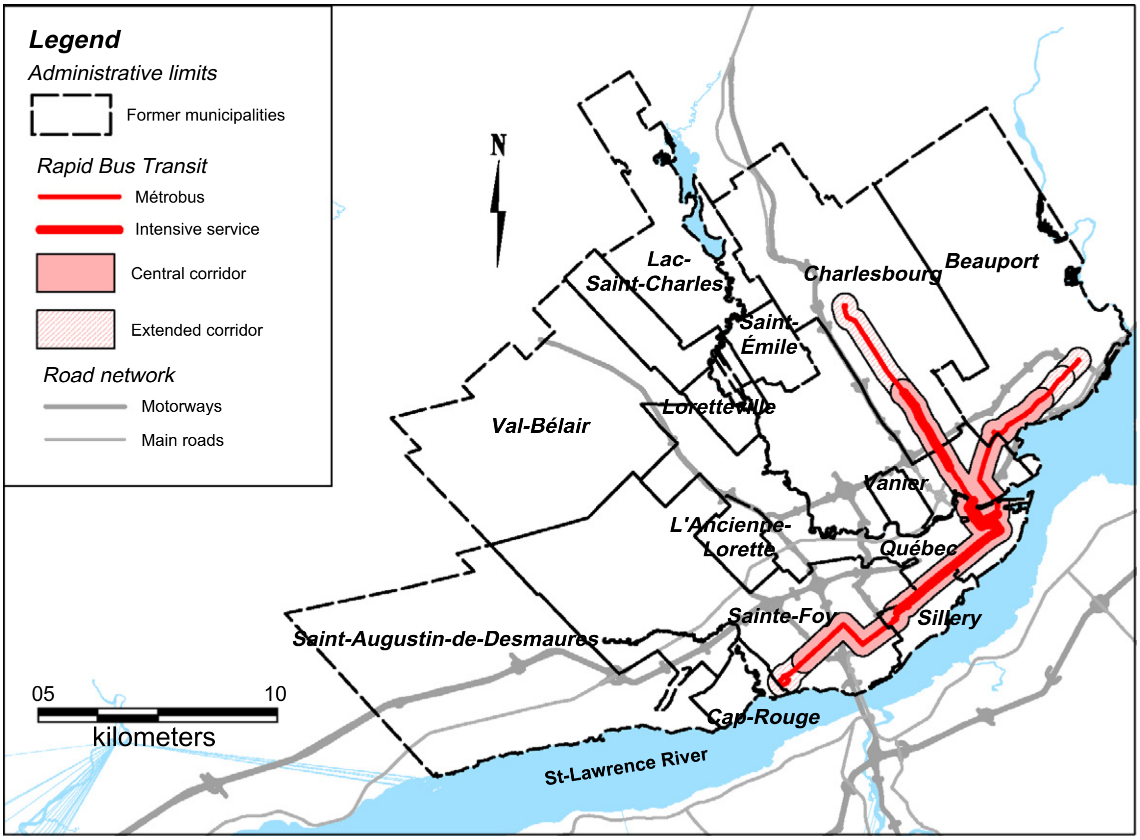
In 1970, the provincial government of Quebec passed a bill to create a public authority aimed at providing transit service on the territory of the former Quebec Urban Community (QUC). This authority had successive denominations (CTCUQ, STCUQ and RTC) at various stages of political restructuring. Early in the 1970s, it consolidated its operations through the expropriation of the six private companies formerly operating in QUC with no tariff integration and low connectivity. The new integrated PT network was constituted of local buses sharing their way with cars on the streets and roads with frequent stops (250 m) along service routes. Most of the time, long distance commutes requested at most two transfers while service to a large territory was rather slow. This first phase ended in 1992 with a restructuration plan.

There are OD surveys in the region every 5 years since 1976. The 1991 OD survey conducted by RTC gave the signal that the service should be restructured. Indeed, the modal share of PT was declining steadily, as a consequence of the addition of several highways during the 1960s and the 1970s and of the ensuing progress in car ownership. Then, two new types of services were inaugurated: (a) a rapid bus transit (RBT) called "Métrobus", and (b) express bus routes using highways to link remote neighbourhoods to the two main regional activity centres, in Old Quebec and Sainte-Foy. However, due to both physical constraints in the bus depot and cost considerations, the restructuring plan was recycling mostly vehicles coming from the dismantlement of the former local routes. Most of the deployment costs of this operation (\$1 M for implementation in 1992; \$0.5 M for extension in 1993 and \$3 M for improvement in 1994–1995) was devoted to implementing reserved service lanes for the Métrobus were possible, providing better sheltering at service points, etc. Obviously these figures do not include operation costs, but they were almost unchanged, the total service time remaining roughly constant. Thus, the operation consisted mostly in service restructuring.[6]

The Métrobus is a rapid bus transit (RBT) service whose purpose is to reduce time spent on commuting by increasing the service frequency while reducing the number of stops and following a straightforward free route. During peak hours, vehicles run every 5–10 min, with increased frequency on more popular routes; a service lane is reserved for buses and taxis, making trips from the outskirts and downtown area easier. In Quebec City, the two Métrobus lines (800–801) provide service to nearly 70 km of streets with 163 stops, 143 of which are sheltered. The average distance between stops is 430 m. Now an integral part of the Quebec City landscape, the Métrobus was officially put into service in August, 1992, before undergoing various changes that led to its current state. The first route change took place in December of the same year, with the lengthening of the eastern corridor (Beauport). Subsequently, the corridor was extended to the north (Charlesbourg) and west (Sainte-Foy) in August of 1993, and again to the east (Beauport) in August of 1995 (Map 1). Since then, the configuration has remained unchanged, although a new service line was added in 2008.

Thanks to the OD surveys, it is possible to trace back the evolution of PT modal shares at various points in time after the RBT implementation, while distinguishing among evolution in the central corridor (1992), in the extensions (1993 and 1995) and the remainder of the QUC (Table 2). At the City wide level, the restructuring plan of 1992 was not sufficient to stop the decrease in PT ridership, while there is some improvement in 2006. The total ridership was decreasing up to 2001 with a low at 115,000 trips per day, followed by a significant increase for 2006 (123,000). But it is on the modal share of RTC buses that the decrease was stronger, from 13.8% in 1991 to 8.2% in 2006, although the negative trend has slowed down in recent years. This is contrasting with the prevalence of the car which, at the same time, was increasing in both absolute and relative terms.

[6] Beginning in 2008, there is currently a more ambitious project for improvement of PT in Quebec City, with a budget over \$60 M, and consisting in adding several new RBT lines, a hundred new articulated buses and a new depot. This improvement, however, has no effect on the present research. In 2009, the total budget of RTC reached \$162 M.



Map 1. Metrobus corridors in the new Quebec City area.

Now, looking at the situation in the RBT corridors, the picture seems better, especially for the central corridor and when considering the trips totally included in the corridor. There, the modal share of buses has experienced a slower decrease and is far superior to what it is in the remainder of the territory and, surprisingly, to what it is in the extended corridor where the position of PT appears particularly weak. Therefore, we can conclude that the implementation of the RBT service was beneficial to the central corridor, but not sufficient to stop the decrease of PT. Considering that the restructuring plan of 1992 was rather modest, this could be seen as a fairly good result.

But the central corridor is serviced not only by RBT, but also by local and express buses. It is why it is worthwhile to look also at the shares of concurrent services in the corridors in order to understand the market coverage of RBT (Table 3). Considering relative frequency of passengers, one can conclude that RBT is responsible for about 40% of PT service in the city, leaving 10% to express buses and 50% to regular routes. However, it is also obvious that, even in the central corridor, where the RBT service clearly dominates, it is complemented by local buses. Again, the extended corridor provides less than 10% of the passengers riding the Métrobus. Thus, we can expect a lower positive externality at this specific location. The supply is there, yielding some traffic and noise, the modal share of PT is lower than elsewhere and absolute ridership is marginal.

For this study, data on single-family house sales (excluding condominiums) concluded between 1986 and 2004 on the former QUC territory, designated the new Quebec City in January, 2002, is used. A first section of the sample data, between 1986 and 1996, is drawn from the appraisal roll of the QUC, while the second section – between 1994 and 2004 – comes from the Multiple Listing Service (MLS) of the Chambre immobilière de Quebec (Quebec Real Estate Board). Given that the two databases differ in structure and in the nature of the information they contain, it becomes even more relevant to use the repeat-sales method. The sample of transactions considered is not exhaustive, but covers the majority of sales conducted during the period, although no sales are available for 1988, 1989 and 1992. With properties being geocoded by their street addresses, a geographic information system (GIS) allows us to manage a database of multiple sales between 1986 and 2004. Of all sales available for the QUC (more than 60,000), 19,400 transactions were repeat sales, forming 11,285 pairs of observations (sale and resale). According to literature, it is one of the largest databases of multiple residential sales (Abraham and Schauman, 1991; Clapp et al., 1991; Case and Shiller, 1989).

On average, nearly five and a half years elapse between the sale and resale of a residence, as opposed to 6.2 years within both central and extended RBT corridors. The average initial sale price stands at \$91,925, as opposed to \$102,168 for the resale price (Table 4). Average lot size is 601 m^2, with more than half of the homes bought and sold being one-story,

Table 2
Evolution of modal shares along the RBT corridors, in Quebec City, from 1991 to 2006.

	Quebec City Total[c]	Central RBT corridor To/from outside	Extended RBT corridor To/from outside	Within RBT Corridors[b]
Trips bus (RTC only)				
1991	149,559	69,180	3183	31,069
1996	121,206	55,619	2144	31,283
2001	114,615	51,701	3330	30,382
2006	123,686	56,830	4071	31,143
Trips car				
1991	693,596	274,174	29,871	82,866
1996	930,802	352,212	40,057	111,745
2001	1006,864	367,559	44,007	117,854
2006	1094,867	364,117	52,053	114,139
Bus modal share (%)[a]				
1991	13.8%	17.9%	7.1%	19.8%
1996	9.2%	12.3%	4.2%	15.1%
2001	8.4%	11.1%	6.0%	14.5%
2006	8.2%	11.9%	6.2%	13.7%
Car/bus odds ratios				
1991	4.64	3.96	9.38	2.67
1996	7.68	6.33	18.68	3.57
2001	8.78	7.11	13.22	3.88
2006	8.85	6.41	12.79	3.66

This table shows a special compilation of detailed (trip level) origin–destination (OD) data located at the street address (or Canadian postal code) level for 1991 (50,808 persons; 111,224 trips; sampling proportion 10.2%), 1996 (60,940 persons; 153,959 trips; sampling proportion 11.7%), 2001 (68,121 persons; 174,243 trips; sampling proportion 12.7%) and 2006 (78,207 persons; 209,849 trips; sampling proportion 13.9%).
These OD surveys were realized by the transit authority (RTC) in collaboration with the Quebec Province's Ministry of Transportation (MTQ) and are expanded with sampling proportions computed by genders and age groups for more than 40 census sub-divisions (using spatial stratification and Canadian Census data of the same year).
[a] Modal share for bus service is restricted to RTC service, the transit authority for Quebec City; it excludes school buses and buses from other municipalities providing access to Quebec City.
[b] Last column is for trips beginning and ending within the RBT corridors.
[c] Column for Quebec City refers to the former Quebec Urban Community limits prior to the amalgamation in 2002.

Table 3
Distribution of passengers according to boarding points and classes of service during a typical weekday, 2001 and 2006.

	RBT ("Métrobus") (%)	Express bus (%)	Local bus (%)	Total (%)
2001–2002				
Central corridor	37.4	5.2	20.1	62.7
Extended corridor	3.8	0.7	2.2	6.7
QUC outside corridors		4.0	26.6	30.6
Total	41.1	9.9	48.9	100.0
2006–2007				
Central corridor	36.8	6.1	20.5	63.4
Extended corridor	3.3	0.7	2.0	6.0
QUC outside corridors		4.4	26.2	30.6
Total	40.1	11.1	48.7	100.0

This table is based on the compilation of passengers boarding buses at specific stops. Since 2001, a large proportion of buses used by RTC are equipped with on board GPS linked to a system that automatically record inboarding and outboarding passengers with time stamp and location. These equipped buses are attributed at random to specific routes every day. Statistics can therefore be computed on the frequency of passengers entering and leaving the vehicles according to classes of service, time of the day, day of the week, season. These relative frequencies are based on data for the Fall, Winter and Spring seasons.

single-family detached houses (bungalows, 58.9%). Cottages and other single-family residences (semi-detached, row-houses) represent nearly one out of five residences (20.3% and 20.8%, respectively). The majority of transactions are conducted in the second quarter of the year, between April and June (44% for sales and 36% for resales).

The sales pairs whose first and second transactions took place before and after the introduction of the RBT, respectively, represent 37% of the total (Table 5). This information, combined with the location of the residence, allows the net effect of the RBT on sale prices to be isolated. Some 6% of all multiple sales (sales pairs) concentrate along the central corridor, in comparison to 4.5% along the extended corridor within a 500 m radius from the route[7] (Map 2). Finally, slightly more than 40% of

[7] Since the average distance between the stops deserve by the RBT service is 430 m, we choose a 500 m buffer to insure that the stops are all include in the corridors. Moreover, to include the possibility that the effect could be non-linear, we use smaller buffer definition to capture the relation.

Table 4
Descriptive statistics of the houses sold twice or more, between 1986 and 2004.

Variables	N	Mean	Standard Deviation	Skewness	Kurtosis	Min	Max
Sale price (Can. dollars)	11,285	91,924.66	36,878	3.1230	20.2590	50,500	550,000
Resale price (Can. dollars)	11,285	102,167.90	42,190	3.4970	28.7384	50,500	825,000
Years between sales	11,285	5.6099	4	0.7614	3.2704	0.0833	18.3333
Build date	11,285	1976	16	−2.8284	21.2552	1750	1996
Bungalow	11,285	0.5886				0	1
Cottage	11,285	0.2026				0	1
Lot size (m^2)	11,285	601.19	313	4.4509	39.0188	62	4864
Sale quarter							
Q1	11,285	0.14754				0	1
Q2	11,285	0.44289				0	1
Q3	11,285	0.21941				0	1
Q4	11,285	0.19016				0	1
Resale quarter							
Q1	11,285	0.25990				0	1
Q2	11,285	0.35915				0	1
Q3	11,285	0.17732				0	1
Q4	11,285	0.20363				0	1

Table 5
Descriptive statistics of dummy variables for location of sales along the RBT corridors.

Dummies variables	N	Proportion	Observations
Sale before Métrobus and resale after	11,285	0.3721	4199
Central corridor			
Between 0 and 50 m	11,285	0.0034	38
Between 50 and 150 m	11,285	0.0110	124
Between 150 and 300 m	11,285	0.0219	247
Between 300 and 500 m	11,285	0.0235	265
Extended corridor			
Between 0 and 50 m	11,285	0.0012	13
Between 50 and 150 m	11,285	0.0057	64
Between 150 and 300 m	11,285	0.0147	166
Between 300 and 500 m	11,285	0.0233	263
Treatment – central corridor			
Between 0 and 50 m	11,285	0.0015	17
Between 50 and 150 m	11,285	0.0042	47
Between 150 and 300 m	11,285	0.0087	98
Between 300 and 500 m	11,285	0.0099	112
Treatment – extended corridor			
Between 0 and 50 m	11,285	0.0007	8
Between 50 and 150 m	11,285	0.0028	32
Between 150 and 300 m	11,285	0.0069	78
Between 300 and 500 m	11,285	0.0113	128

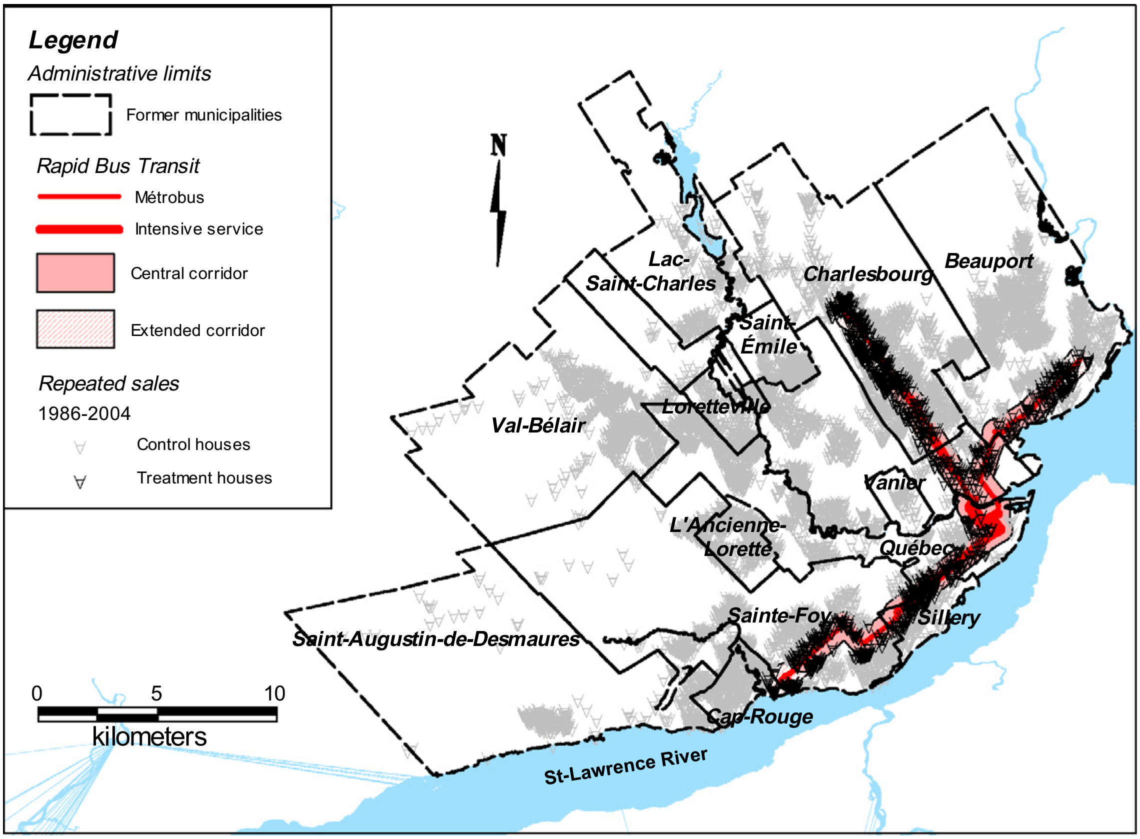
properties located in the central corridor were sold before the introduction of the new RBT system and resold after. For the extended corridor, nearly half the homes (48.6%) were sold before the introduction and resold after.

4. Findings and results analysis

This section comprises three sub-sections. First, it must be established whether the change in PT supply had a significant effect on the resale price of houses located in the corridors served. Secondly, the significant results are used to calculate the economic impact of changes in real estate values on the tax revenue of those former municipalities served by the RBT. Finally, the impact of the results is discussed from a broader viewpoint.

4.1. Impact of the modification of the PT supply on sales prices

The first step involves calculating a price index using the parameters obtain from results of the model estimate for single-family houses in the QUC between 1986 and 2004, without integrating any other explanatory variables in the model (Model



Map 2. Spatial distribution of repeated sales over Quebec City from 1986 to 2004.

Table 6
Transaction rate and ownership duration according to location of houses.

Location	Transactions	Houses	Transaction rate		Time between sales (years)	
	N	*N*	Proportion (%)	Sign	Mean	Sign
Central Corridor	674	6720	10.0	*	6.1574	
Extended Corridor	506	4568	11.1		6.1479	
Elsewhere (in QUC)	10,105	76,206	13.3		5.5464	
Total – QUC	11,285	87,494	12.9		5.6099	

Legend: * $p < 0.1$; ** $p < 0.05$; *** $p<0.01$.

1 – Table 7). It determines the average residential price evolution in the region and serves as a reference for selecting variables meant to measure the impact of a modification in the PT supply.

The estimates show that the rise in prices, in nominal value, continued in the second half of the 1980s only to slow down considerably during the 1990s. Following a price decline between 1994 and 1999, prices resumed their ascent. The market recorded a strong growth at the start of 2000. Thus, between the end of 1999 and the fourth quarter of 2004, prices rose by 39%.

Although the price index is estimated with a large number of pairs of transactions, thus reducing the risk of bias on the estimated index, some issues are raised in the literature as to the accuracy of such an index. In this case, the index curve (Fig. 1) does not seem to be influenced by the sample composition (Clapp and Giacotto, 1992; Clapp et al., 1991; Case et al., 1991) since the estimated index remains practically unchanged regardless of the number of multiple resales considered. Moreover, Steele and Goy (1997) suggest the calculation of a series that allows us to gauge the presence of biases in the price index. These are deemed weak[8] and the index remains within the confidence interval at a threshold of 5% (Fig. 2). Lastly, the temporal pattern (Sommervoll, 2006) is appropriate, given the absence of any strong volatility in prices over time.

[8] Bias is so small that by subtracting the correction for possible bias as suggested by Steele and Goy (1997) from the uncorrected estimated index, the latter remains within the limits of the confidence interval. Thus we can conclude that the estimated index is not (or very lightly) biased.

Table 7
Estimation results by repeated sales approach; 1986–2004.

Variables	Repeated sales					
	Model (1) (base)		Model (2) (Métrobus)		Model (3) (Métrobus – WLS correction)	
	Coefficient	*t* stats	Coefficient	*t* stats	Coefficient	*t* stats
1986-Q2	0.0154	*1.43*	0.0155	*1.44*	0.0166	*1.48*
1986-Q3	0.0391	*3.52*	0.0388	*3.50*	0.0391	*3.39*
1986-Q4	0.0539	*4.60*	0.0538	*4.60*	0.0581	*4.83*
1987-Q1	0.0658	*5.01*	0.0666	*5.06*	0.0731	*5.36*
1987-Q2	0.1120	*8.79*	0.1128	*8.86*	0.1153	*8.95*
1990-Q1	0.2650	*22.01*	0.2643	*21.95*	0.2654	*21.52*
1990-Q2	0.2794	*27.06*	0.2783	*26.95*	0.2783	*25.98*
1990-Q3	0.2771	*24.97*	0.2764	*24.92*	0.2770	*24.25*
1990-Q4	0.2753	*24.18*	0.2752	*24.19*	0.2770	*23.71*
1991-Q1	0.2763	*21.59*	0.2755	*21.52*	0.2770	*21.30*
1991-Q2	0.2840	*27.30*	0.2837	*27.28*	0.2859	*26.54*
1991-Q3	0.2922	*27.33*	0.2915	*27.28*	0.2945	*26.69*
1991-Q4	0.2934	*25.68*	0.2925	*25.60*	0.2955	*25.34*
1993-Q1	0.2980	*24.42*	0.2958	*24.22*	0.2966	*23.89*
1993-Q2	0.3224	*31.44*	0.3207	*31.26*	0.3231	*30.39*
1993-Q3	0.3142	*28.92*	0.3127	*28.76*	0.3153	*28.24*
1993-Q4	0.3137	*28.82*	0.3124	*28.69*	0.3163	*28.56*
1994-Q1	0.2993	*24.92*	0.2981	*24.81*	0.3042	*25.31*
1994-Q2	0.3231	*31.78*	0.3216	*31.60*	0.3237	*30.66*
1994-Q3	0.3298	*29.46*	0.3285	*29.33*	0.3306	*28.95*
1994-Q4	0.3040	*27.16*	0.3024	*27.01*	0.3051	*27.00*
1995-Q1	0.2919	*23.22*	0.2904	*23.10*	0.2951	*23.75*
1995-Q2	0.3034	*29.16*	0.3020	*29.01*	0.3052	*28.42*
1995-Q3	0.2999	*26.42*	0.2987	*26.30*	0.3004	*26.04*
1995-Q4	0.2887	*26.28*	0.2873	*26.14*	0.2903	*25.99*
1996-Q1	0.2734	*23.46*	0.2718	*23.31*	0.2778	*23.73*
1996-Q2	0.2871	*27.29*	0.2856	*27.12*	0.2892	*26.68*
1996-Q3	0.2874	*24.60*	0.2858	*24.44*	0.2869	*24.20*
1996-Q4	0.2727	*23.41*	0.2709	*23.24*	0.2743	*23.18*
1997-Q1	0.2829	*25.46*	0.2814	*25.32*	0.2839	*24.96*
1997-Q2	0.2937	*26.32*	0.2920	*26.15*	0.2945	*25.76*
1997-Q3	0.2785	*21.96*	0.2762	*21.75*	0.2780	*21.78*
1997-Q4	0.2732	*22.22*	0.2718	*22.09*	0.2728	*21.91*
1998-Q1	0.2762	*23.98*	0.2749	*23.86*	0.2784	*23.61*
1998-Q2	0.2799	*24.10*	0.2782	*23.93*	0.2832	*23.92*
1998-Q3	0.2436	*18.61*	0.2422	*18.49*	0.2447	*18.54*
1998-Q4	0.2744	*22.18*	0.2722	*21.98*	0.2722	*21.62*
1999-Q1	0.2786	*24.30*	0.2770	*24.14*	0.2817	*23.85*
1999-Q2	0.2915	*25.36*	0.2899	*25.20*	0.2935	*24.87*
1999-Q3	0.2581	*20.72*	0.2559	*20.52*	0.2596	*20.51*
1999-Q4	0.2813	*23.48*	0.2799	*23.34*	0.2828	*23.04*
2000-Q1	0.2936	*26.00*	0.2922	*25.85*	0.2956	*25.30*
2000-Q2	0.3032	*26.89*	0.3016	*26.73*	0.3051	*26.23*
2000-Q3	0.3036	*23.49*	0.3013	*23.30*	0.3002	*22.66*
2000-Q4	0.3240	*26.61*	0.3222	*26.45*	0.3245	*25.80*
2001-Q1	0.3330	*29.50*	0.3316	*29.35*	0.3346	*28.52*
2001-Q2	0.3348	*29.20*	0.3333	*29.06*	0.3396	*28.67*
2001-Q3	0.3497	*28.09*	0.3487	*28.00*	0.3515	*27.24*
2001-Q4	0.3713	*31.46*	0.3696	*31.30*	0.3700	*30.21*
2002-Q1	0.4028	*36.38*	0.4009	*36.12*	0.4067	*35.22*
2002-Q2	0.4432	*37.85*	0.4417	*37.70*	0.4419	*36.27*
2002-Q3	0.4627	*34.50*	0.4611	*34.37*	0.4629	*33.27*
2002-Q4	0.5012	*41.40*	0.4996	*41.26*	0.5039	*40.02*
2003-Q1	0.5577	*46.91*	0.5561	*46.75*	0.5614	*45.59*
2003-Q2	0.5797	*46.43*	0.5779	*46.26*	0.5820	*44.59*
2003-Q3	0.6210	*49.11*	0.6194	*48.96*	0.6211	*47.19*
2003-Q4	0.6440	*52.63*	0.6431	*52.51*	0.6493	*50.40*
2004-Q1	0.6975	*58.18*	0.6962	*58.03*	0.6964	*55.53*
2004-Q2	0.7081	*57.92*	0.7063	*57.71*	0.7125	*55.35*
2004-Q3	0.7211	*53.92*	0.7201	*53.82*	0.7237	*51.78*
2004-Q4	0.7497	*44.98*	0.7483	*44.91*	0.7511	*44.28*
Impact – central corridor						
Between 0 and 50 m			−0.0390	*−1.39*	−0.0318	*−1.06*
Between 50 and 150 m			0.0639	*3.78*	0.0685	*3.63*
Between 150 and 300 m			0.0256	*2.17*	0.0279	*2.19*

(*continued on next page*)

Table 7 (*continued*)

Variables	Repeated sales					
	Model (1) (base)		Model (2) (Métrobus)		Model (3) (Métrobus – WLS correction)	
	Coefficient	*t* stats	Coefficient	*t* stats	Coefficient	*t* stats
Between 300 and 500 m			0.0092	*0.83*	0.0109	*0.90*
Impact – extended corridor						
Between 0 and 50 m			−0.0519	*−1.27*	−0.0344	*−0.80*
Between 50 and 150 m			−0.0159	*−0.78*	−0.0103	*−0.49*
Between 150 and 300 m			−0.0162	*−1.23*	−0.0122	*−0.88*
Between 300 and 500 m			0.0037	*0.36*	0.0020	*0.19*
N	11,285		11.285		11 285	
Moran's *I* statistic			0.0156		0.0148	
White test statistic[a]			242.4572		5.3422	
R^2	0.7046		0.7053		–	

[a] The critical value of the White test at 95% is 9.4877.

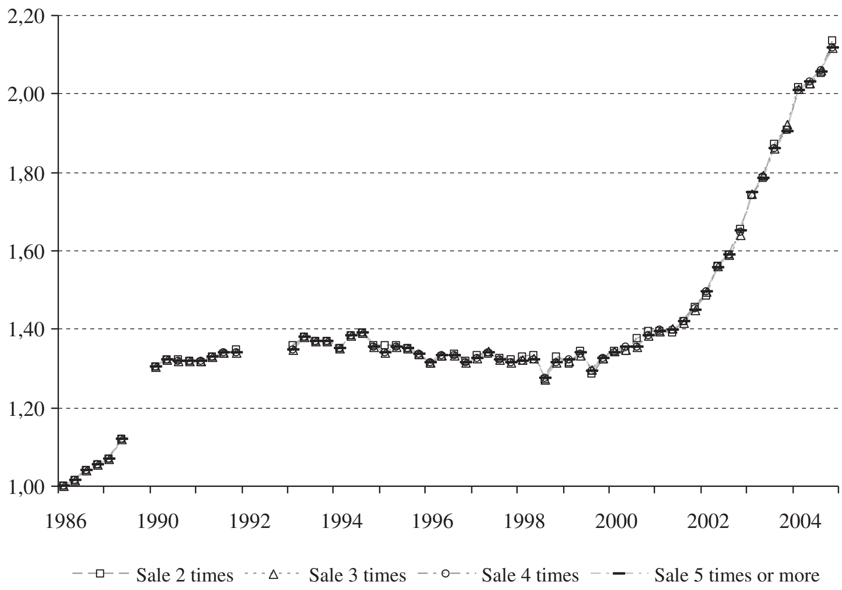


Fig. 1. Price indexes evolution according to sample composition; QUC, 1986–2004.

Another criticism about the repeat-sales approach is rooted in the possible presence of a selectivity bias, which would increase the probability of some properties to be bought or sold more often than others. Although indirect, one way to ensure that the sample available within the corridors with service by the RBT is not affected, namely by speculation, is to compare the frequency of multiple transactions with that of all sales recorded in the residential stock. The ratio of transactions on total stock is lower in the service corridors than in the remaining QUC territory (Table 6), suggesting that the multiple transactions recorded are not of a speculative nature within a 500-m radius of the service corridors. Moreover, the average ownership time, measured by the time elapsed between sales, is higher within the corridors than outside them. The selected sample does not show significant differences, for a 95% threshold with a two-tailed test, either in the frequency of transactions or in the average time-lag between sales, within or outside the RBT corridors. Thus the database does not exhibit special characteristics linked with RBT corridors.

The second model introduces control variables for the PT supply using the difference-in-differences (DID) estimator (Model 2 – Table 7). The addition of variables identifying the impact of the RBT does not substantially increase the explanatory power of the model. However, results are in line with expectations to the extent that residences located very close to the route (less than 50 m) have, on average, a lower sales price than before the introduction of the Métrobus. This situation can be explained by the dominance of negative externalities, linked to the increase in traffic and noise generated by a higher frequency of buses, over the improvement in accessibility. However, the relationship is not statistically significant, which limits the interpretation that can be drawn from the net impact for residences located less than 50 m away.

In the central corridor, those houses located more than 50 m away from the RBT route recorded a positive change in the home sales price. As suggested by Chen et al. (1997), this effect decreases with distance. In other words, the impact of the new service diminishes with an increase in the walking distance (or time) to the route. The effect becomes negligible at a

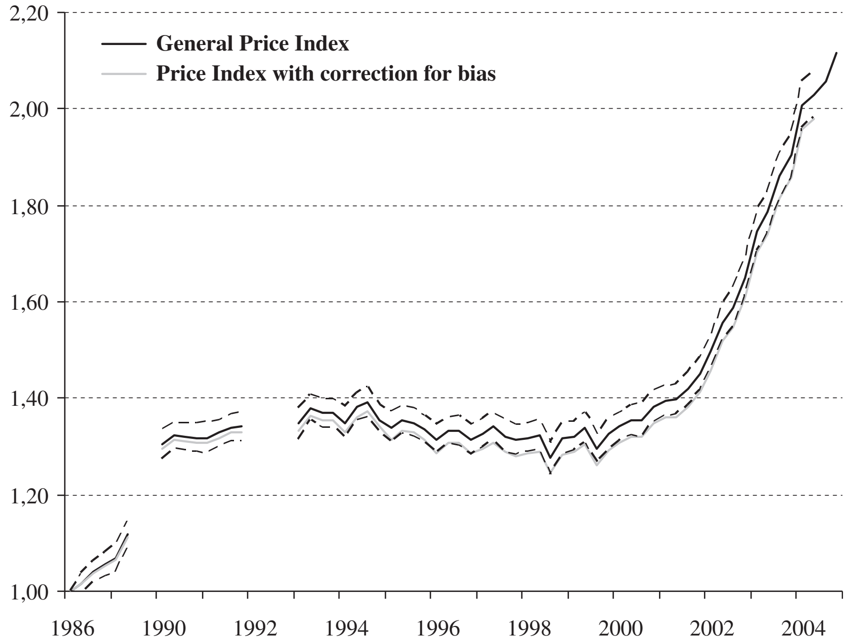


Fig. 2. Price index evolution with bias correction (Steele et Goy, 1997); QUC, 1986–2004.

distance beyond 300 m. Only those residences located between 50 and 300 m recorded a significant increase in sales prices following the introduction of the new service with the market premium standing at 6.4% for properties located between 50 and 150 m of the Metrobus service and falling at 2.6% for homes located between 150 and 300 m.

Those residences located along the extended corridors (that were added after the inauguration of the service in August of 1992) show a different rent pattern. The negative effect extends farther away before turning positive. Within 300 m from the route, the estimate coefficients suggest that the negative externalities dominate the benefits linked to accessibility. The effect becomes positive between 300 and 500 m. However, the estimated impact of the modification in the PT service supply does not have a statistically significant influence on the prices of residences located along these routes. There is no significant relationship at a 95% confidence level. This can be explained, in part, by the substitution between car and bus service that doesn't occur there. Since Quebec City is a small urban area, car travel time remains lower than bus travel time for these extremities of the RBT service network, especially considering the configuration of the highway network. That is, there is no real interest for car owners to use the new bus service since pertaining time cost is still higher than for the car.

This said, using White's (1980) test, the model reveals a heteroskedasticity problem in the estimated variance, thus invalidating the usual assumptions underlying tests on the significance of the results. In order to correct variance components, and thus ensure that the net effect is significant, the weighted least squares transformation, suggested by Case and Shiller (1989), is applied. The results suggest that the above conclusions remain valid (Model 3 – Table 7): only those residences located in the central corridor between 50 and 300 m and served by the new RBT are assigned a market premium stemming from its introduction.[9]

In analyses that include a geographic dimension, error terms can be correlated among themselves and this spatial dependency phenomenon can invalidate the conclusions. The coefficients of spatial autocorrelation on residuals (Moran's *I*) are very weak (Table 7), but remain statistically significant.[10] One glitch in interpreting the significance of coefficients stems from the lack of consideration for the temporal dimension in calculating indices. Given that the estimates are based on a period that spans nearly 20 years (1986–2004), the calculation of spatial autocorrelation implicitly suggests that the increase in sales prices between 1986 and 1990 is linked to the rise in prices recorded between, say, 2000 and 2004. It is conceptually difficult to link past growth to future growth since the longitudinal profile is unknown *a priori*. Thus, interpreting these longitudinal coefficients becomes clearly less trivial than when analyses consider only the spatial dimension. For these reasons, and given the weakness of the estimated coefficients, the use of autoregressive spatial models would appear to have little impact on estimates. The significance of the coefficients of the last models in Table 7 is considered strong since the issue of variance heterogeneity is

[9] In order to countercheck the robustness of the results, the same experience is repeated with the Fourier expansion method as the price index device measurement. The results obtained show that the conclusions are identical to those of repeat sales. Not only are the signs the same, but the coefficients are comparable.

[10] The calculation of probabilities is done using the GeoDA software package (Anselin et al., 2006), varying the number of permutations. The higher this is, the higher the significance of the coefficient is.

Table 8
Partial economic impact of the "Métrobus" RBT service, 1992–2004 (in 2004 Canadian dollar values).

	Impact in central corridor	
	50–150 m	150–300 m
Property transfer taxes	23,491 $	15,302 $
Municipalities tax revenues	3042,396 $	2145,329 $
Owner's profits	613,067 $	513,882 $
Owner's anticipated profits	20,887,407 $	14,978,128 $
Total impact estimated	24,542,871 $	17,637,339 $

corrected (test statistics are lower than critical values – Table 7) while spatial autocorrelation of residuals is weak, as should be the case.

4.2. Economic impact of the supply change in the PT service

Results are in line with previous findings from studies conducted in Bogotà, Columbia (Rodriguez and Mojica, 2009; Mandieta and Perdomo, 2007; Munoz-Raskin, 2006; Rodriguez and Targa, 2004), although the magnitude of the PT coefficient is slightly lower. This may reflect differences in urban size as well as in climate, which has an impact on ridership and utilization of the services. This being said, our findings mirror actual willingness-to-pay (WTP) since the dependent variable reports real sales prices instead of asking prices, which could yield substantially different results. This true WTP can then be translate into global economic impact.

For corridors where they are significant, the impacts on sales prices are transposed in constant dollar equivalents in order to estimate the immediate economic effect of any modification in PT supply. This evaluation is based on the argument according to which the change in the sale prices has repercussions on the profits earned by owners at the time their house is sold as well as on municipality revenues, who receive fiscal benefits from the increase in residential values through indexation of the local appraisal rolls and money inflows from transaction taxes.

4.2.1. . . . on owners' assets

The increase on single-family residential values also has an effect on the return on investment for before-1992 owners of residences located between 50 and 300 m along the central corridor. For those who sold their home, the appreciation connected to the introduction of a new PT service resulted in a profit. Thus, according to the time of sale, the bonus, or seller's marginal profit – π, is obtained by multiplying the capitalized final sales price (2004), $P_{i,t}$, by the estimated percentage location rent effect, ϕ_j. The owners' total profit is capitalized in order to harmonize the figures in calculating the final and total impact of property sales in the database.[11]

$$\pi = \sum_{i=1}^{I} \sum_{t=1993}^{2004} (1+r)^{(2004-t)} [P_{i,t}\phi_j] \tag{8}$$

Thus the introduction of the new public transportation service results in total bonuses of approximately \$1.1 M in 2004 values (Table 8).

Lastly, those owners who have not yet sold their residence since the introduction of the service still have the possibility of benefiting from the capital gain at the time of sale. Thus, this situation represents a real asset that takes the form of an anticipated profit, π^*, which is assessed as of 2004 based on the expected market price, $P^*_{i,\bar{t}}$, and the estimated location rent effect (from Eq. (5′)), ϕ_j (Eq. (9)).

$$\pi^* = \sum_{i=1}^{I} P^*_{i,\bar{t}}\phi_j \tag{9}$$

The expected market valuation for the housing stock not having registered any transaction since 1992 is established based on an average ratio that allows the estimated appraisal rolls to be converted into market price. For each home bought or sold in 2004 in each of the former municipalities, this ratio is calculated based on the average active price and average assessment. The factor for real estate appraisal rolls, which varies between 1.3 and 1.36 according to location, is then applied to the 1997 appraisal roll, indexed with the price index to reflect 2004 values. In total, this asset represents more than \$35 M (Table 8), the largest portion of profits.

This amount is subsequently collected both by owners at the time of sale, and by municipalities since property taxes have increased since 1992, following the introduction of the new RBT service. Even though we cannot accurately identify the portions that will be attributed to owners and municipalities, these assets remain a substantial economic benefit.

[11] Given the structure of the database, only repeated sales are included in the estimate. A full estimate should include all of the transactions. However, in evaluating owners' assets, this amount is implicitly included although underestimated, given the capitalization of results.

4.2.2. ... on tax revenue

An increase in the price of single-family homes has a one-shot impact and a recurrent impact on the municipality's tax revenues. On the one hand, raising prices results in an increase in the amount of real estate transfer taxes paid by the buyer upon purchase. On the other hand, an increase in market values has a positive effect on the real estate appraisal roll, given that it is indexed according to market evolution. Thus, an increase in market values normally results in the equivalent increase in values recorded in appraisal rolls. This has a direct, recurrent, although not necessarily proportional, negative effect on the tax burden of owners of property located between 50 and 300 m of the central corridor.

The impact on tax revenues pertaining to real estate transfer taxes is calculated on the sales price.[12] In Quebec, transfer taxes are based on a progressive rate. The rate varies according to the transaction price and is split up over three rates. The first rate, τ_1, for prices less than \$50 000 (x_1), is 0.5%. The second level, τ_2, is set at 1.0% for any amount exceeding \$50,000, up to \$250,000 (x_2). Finally, for any transaction price greater than \$250 000, the surplus is taxed at a rate of 1.5%, τ_3. Thus the amount of transfer tax for a residence (i), TT_i, is calculated based on the selling price, P_i, by applying the mathematical formula described in the following equation:

$$TT_i = \begin{cases} \tau_1 P_i \quad \text{if } P_i \leqslant x_1 \\ \tau_1 x_1 + \tau_2(P_i - x_1) \quad \text{if } x_1 < P_i \leqslant x_2 \\ \tau_1 x_1 + \tau_2(x_2 - x_1) + \tau_3(P_i - x_2) \quad \text{if } P_i > x_2 \end{cases} \tag{10}$$

The fiscal impact of a price increase on the municipality's tax revenues, FI_{TT}, is first established by calculating the total amount of real estate transfer taxes disbursed during the sale of a residence i in the corridors affected by the change in values during the sale in time t, $TT_{i,t}$. We then calculate the total amount that would have been disbursed if there had been no change in the selling price, $TT^0_{i,t}$, that is, assessed at the selling price as unaffected by the premium ϕ_j, P^0_i. The difference between the two amounts, the marginal contribution, is attributed to the introduction of the RBT. The tax earnings realized on the transfer tax[13] is described using Eq. (11).

$$FI_{TT} = \sum_{i=1}^{I} \sum_{t=1993}^{2004} (1+r)^{(2004-t)} \left[TT_{i,t} - TT^0_{i,t} \right] \tag{6.11}$$

The capitalization rate, r, is set at 6.5%[14] and allows amounts to be readjusted to 2004 values. Thus, results are expressed in 2004 dollar values.

The modification of selling prices also has repercussions on tax revenues based on the appraisal roll. An increase in prices has a direct effect on the indexation of rolls and, consequently, on the amount of local taxes collected. The impact is recurrent since we assume that the increase in values stemming from the introduction of the RBT remains stable as long as the service continues to exist. The monetary impact, FI_{VR}, is thus calculated according to a two-stage procedure for residences located within the corridors that recorded a significant change in the selling price. The first stage involves calculating the amount of local property taxes for all residences i located in the affected corridors and for each of the t years following the date of service introduction, $LT_{i,t}$, up to 2004.[15] The data for the 1997 appraisal roll are used for the calculation baseline, which is indexed for each year based on the pricing index previously estimated (Model 3 – Table 7). The amount of local property taxes collected is defined by the product of the residential realty assessment, $VR_{i,t}$, and the tax rate in effect for each of the municipalities, $\tau^m_{i,t}$.

$$LT_{i,t} = \tau^m_{i,t} VR_{i,t} \tag{12}$$

In the second stage, the amount of property taxes charged following the modification of the PT supply is calculated by applying the percentage value change, ϕ_j, obtained by the econometric model for each of the corridors where the effect is significant. The results are estimated on the 2004 base using the capitalization rate.

$$FI_{VR} = \sum_{i=1}^{I} \sum_{t=1993}^{2004} (1+r)^{(2004-t)} [LT_{i,t}\phi_j] \tag{13}$$

Total tax benefits are estimated at more than \$5.2 M in 2004 values (Table 8). More than 99% of the total tax benefits come from the increase in residential local property taxes, leaving only a marginal impact for the increase in tax revenues stemming from the transfer tax, which only represents a one-shot impact.

[12] Through this method, it is implied that the sale price is higher than the municipal appraisal value at time of sale since the tax is applied to the greater of the two amounts.

[13] The impact obtained is probably underestimated, since we do not have data for all transactions that took place in the region between 1992 and 2004. Moreover, the effect on school board tax variation is not considered here. However, it is impossible to quantify this under-evaluation based on available data.

[14] This rate is set at the average cost of capital borrowing to the municipality.

[15] Under the local appraisal system prevailing in Quebec, appraisal values are fixed for 3 years; in this paper, the PT supply change impact on values is simulated using a progressive, annual market adjustment of appraisal values.

4.2.3. Overall economic benefits

Although these benefits are quite substantial, they must be interpreted in the light that they remain partial and incomplete. Indeed, for the time being, only the impact pertaining to single-family residential housing stock is accounted for and the owner's asset portion is calculated without considering that part of the plus-value will be paid back through higher property taxes. In order to draw a complete picture of the economic benefits pertaining to the introduction of the RBT service, the study would have to be expanded so as to include condominiums, apartment building incomes, businesses and vacant lots, which we cannot do given the lack of suitable data. Moreover, a complete analysis should take into account the possibility that municipalities could pay back the benefits ensuing from a better PT mode by reducing the tax burden to individuals, so that the future potential benefit remains unknown and uncertain.

This being said, theses potential benefits can growth according to such parameters as the utilization rate, congestion, service quality, demographic characteristics and the socio-economic status. Theses different parameters, still unknown and unpredicted for future, can change the potential of PT impact for both, municipalities and owners. That is, better logistical organisation of the existing PT services in Quebec City can also consolidate and ameliorate the estimated impact. For theses reasons, the impact estimate here is quite conservative and should only be interpreted, we believe, as a lower bound of the total potential impact.

4.3. Discussion

The model developed in this paper enables us to evaluate the impact of a change in public policy regarding residential valuations and the resulting fiscal impact. To the best of our knowledge, this is the first time this type of estimator has been used to measure the net impact of a new PT service by comparing a control effect group with a treatment group before and after a supply change, with hedonics being used for estimating local tax and other economic benefits. The approach presented allows us to overcome several problems, such as the omission of variables and the choice of the functional form, keeping in mind two assumptions: (1) that the relative importance of each component of the hedonic price is constant over time (thus they evolve at the same rhythm) and (2) that residences are of same quality and have not undergone major renovations. From the perspective that repeated sales are representative of all transactions, the model allows us to solve the majority of issues related to heteroskedasticity and spatial autocorrelation of error terms, while maintaining a relatively simple estimation model.

However, this study overlooks an important aspect in the calculation of the overall economic impact: it omits the tax revenues accruing from the apartment rental and business/commercial sectors. Debrezion et al. (2007) recently conducted a meta-analysis, based on 54 studies dealing with the impact of the presence of PT on prices that sheds light on the differences in existing estimates. The authors show that the impact on the commercial sector is approximately 12 percentage points higher than that for the residential sector. Moreover, the type of PT considered influences the effects estimated. In the case of buses, premiums are 1% lower on average than for light rail transit systems. Cervero and Duncan (2004) suggest that the modal share of PT also influences the location rent associated with proximity to the service. Our results for the extended corridor support this point of view that the impact only appears when the service is widely used, making its access a valuable asset for home seekers. Thus the return on investment depends on several variables, which illustrates the critical importance of developing a PT that is truly competitive with the automobile.

These findings are important because the modal share of PT is quite low in the QUC while the RBT corridor where the impact is significant is primarily located in a sector where average income levels and private car use are higher. Modifying the PT supply is not sufficient, in the extended corridor zones (areas that are less populated), for countering the disturbances of its operation or to provide a true substitute to the automobile, given the high accessibility to the highway network. In Quebec City, express buses seem to be more appreciated in those remote, low-density neighbourhoods (Des Rosiers et al., 2010). Thus, it is possible for a PT service to generate variable results based on the structure of the urban fabric and socio-economic characteristics of the city's various neighbourhoods. In Quebec City, the estimated economic impact for the single-family residential market is probably only the tip of the iceberg, and a complementary study is required in order to address the issue adequately.

This being said, the study does show that the new RBT service had a noticeable impact on the municipality's tax revenues. Economic impact studies would allow municipalities to optimize the functional organization of PT networks in conjunction with an improvement in the service to citizens in order to increase their tax base, especially in neighbourhoods where PT already holds an important modal share. In addition, a PT supply that is properly designed considering the current demand could potentially increase net tax benefits for the service. As stressed by Landis et al. (2004), location rents linked to the PT also depend on the quality of services offered and on the possibility of combining several methods to travel (develop park-and-ride centres, for example). So et al. (1997) arrived at very similar conclusions. To be optimal, the PT service must fit in with the socio-spatial structure of its surroundings (Lewis-Workman and Brod, 1997).

Location rent shaping through adequate planning policies is another aspect that can influence indirect tax revenues generated by PT. Weinburger (2001) argues that the capitalization of proximity rents in prices and their effect on the real estate appraisal roll should be used in part to finance the PT service. Our study shows that, in some way, improving the PT supply has repercussions on tax inflows for the municipalities, which can be used to finance or improve the service.

5. Conclusion

Based on the hedonic theory, this paper develops an analytical framework that allows us to determine the economic impact (partial) of a public policy on a given population. The characteristics of the data (coming from two distinct databases) render the use of the normal hedonic price models difficult. The repeat-sales approach, designed on the transformation of the hedonic price equation in combination with the introduction of the difference-in-differences estimator, allows us to use data that come from sources where the property characteristics are processed in a heterogeneous manner. The first-difference model allows us to obtain the net portrait of a modification in the PT service, while properly controlling for problems related to heteroskedasticity and the spatial autocorrelation of error terms.

In Quebec City, the advent of a rapid bus transit (RBT) service in the central corridor, characterized by a higher residential density, has modified the prices of single-family residential homes. Only properties located far enough away from the negative effects of an increase in bus traffic, but sufficiently close to walk to the service, experienced a significant increase in their sale price. This is particularly important since this effect is positively related to the degree of utilization of the service as well as with the type of clientele. The sale prices of residences located in other corridors studied did not change significantly, given the weak elasticity of substitution between the PT and the personal automobile in the urban context of Quebec City. This situation can, in part, be the result of highway proximity for this part of the city.

The translation of these effects in terms of economic impact for municipalities shows that there exists a return on investment. The introduction of the new RBT system (actual implementation cost of $8.8 M in 2004 value) resulted in benefits of more than $6 M for municipalities and $35 M for single-family residence owners. While the return on investment is substantial, its evaluation remains conservative. Using the profits from a PT supply enhancement to defray a part of the service costs while designing the PT route in order to optimize property tax revenues constitute a promising avenue for municipalities, even more so considering it would probably be congruent with improved service for users.

With the arrival of a new RBT route in Quebec City in 2008 and the planning of other routes in the near future, it will be interesting to test whether the positive fallout of the RBT, as measured in this paper, is a lasting one and applies to other routes. The idea of optimizing routes in order to maximize the tax impact through raising location rent could likely be tested in this context within a few years.

The study also sheds light on a potential problem of fiscal equity linked to the sharing of the tax burden resulting from the change in the PT supply. If residences located near the RBT route saw their value increase following its introduction, real estate tax assessment appraisal methods, which are based on the use of 'comparable' residences, may bias tax-purpose assessment values. Using residences located along the RBT route in order to infer a value for a residence located outside the corridors will result in its overvaluation, thereby generating a tax iniquity for some homeowners. Outside specific zones, the market values do not change significantly. Moreover, according to Lin and Hwang (2003), inequity is reinforced by the fact that proximity to the PT reduces the effect of age and distance from services in the hedonic price equation. Of course, these arguments are only hypothetical and additional research is necessary to further explore the problem of tax fairness linked for the greater part to real estate property assessment methods.

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