Introduction

Colon cancer is the 3rd most common cancer in both males and females in Canada (1,2). Surgical excision of the affected colon – a colectomy – is the recommended treatment for most patients diagnosed with colon cancer (3). Historically, the standard approach to colectomy was through an open procedure typically via a midline laparotomy incision. The required long incision, manual manipulation of tissue and associated blood loss cause an exaggerated physiological stress response, prolonged paralysis of bowel (ileus) and increased requirement for opioid analgesia, all of which impairs postoperative recovery. In the late 1980s, surgeons began evaluating laparoscopic colectomy (LC) as an alternative to open colectomy (OC) (4), and by 2004, randomized controlled trial evidence clearly demonstrated that LC for colon cancer accelerated postoperative recovery, reduced duration of hospital stay, and reduced postoperative pain /narcotic requirements while providing equivalent oncologic outcomes (recurrence, survival) when compared to OC (5-9). The adoption of LC for colon cancer in the later part of the first decade of the twenty-first century has been demonstrated in several countries; LC rates in the US increased from 11% in 2007 to 45% in 2009 (10,11). From 2009 to 2014, LC rates increased from 30% to 61% and from 9% to 30% in the Netherlands and Sweden respectively. In South Korea, 65% of patients with colon cancer underwent LC in 2014, compared to 44% in 2008 (12).

There are few population-based data from Canada describing the uptake of LC: data from Ontario show that between 2002 and 2009, the proportion of elective colectomies done laparoscopically increased from 13% to 37% (13). In British Columbia, the proportion of colon cancer patients undergoing LC increased from 2% to 25% between 2003 and 2008 (14). To date, published population-based data from other provinces do not exist.

The objective of our study was to examine the uptake of LC in Canada, and specifically compare its use among all Canadian provinces (except Quebec) while identifying other factors associated with LC.

Methods

This study included all patients undergoing elective colectomy for colon cancer in Canada identified through the hospital Discharge Abstract Database (DAD) maintained by the Canadian Institute for Health Information (CIHI) (15) between April 1, 2004 and March 31, 2015 (fiscal years 2004 – 2014). Patients from Quebec were not included as data from that province are not reported to CIHI. Patients with an International Classification of Diseases and Related Health Problems, 10th Revision, Canada (ICD-10-CA) (16) primary diagnosis of colon cancer (C18.0-18.9 or C19) and a Canadian Classification of Health Intervention (CCI) (17) procedure code for colectomy (1.NM.87, 89, 91 or 1.NQ.87) were identified, and those without a valid Canadian 3-digit postal code and aged ≤ 17 years of age were excluded. In order to best identify a cohort eligible for both OC and LC, the following exclusion criteria were applied (Appendix A; online only): 1) multivisceral resection; 2) concomitant hepatic metastasectomy; 3) pregnancy; and 4) emergency presentation (peritonitis, bowel obstruction or admission via the emergency room). OC and LC were differentiated using CCI codes (Appendix 2).

Demographic (age, sex, year of surgery, rural/urban residence, and province of residence), patient (Elixhauser comorbidity index, segment of colon resected), and system (average annual hospital and surgeon colectomy volume) characteristics were identified on the DAD record. Rural/urban residence was determined according to the forward sortation area based on the first 3 digits of the 6-digit Canadian postal code. For average annual hospital and surgeon volumes, the average number of colectomies for years in which at least one colectomy was performed was

calculated for each surgeon and hospital. The average volumes were categorized into quartiles and then dichotomized into high and low, defined as above and below the 75th percentile. Therefore, a high-volume surgeon would on average perform more than 7 colectomies per year and at least 37 colectomies would be performed annually in a high-volume hospital.

Analysis

The number and proportion of patients undergoing OC or LC were reported by province and year. The association between LC and each predictor variable was assessed by simple logistic regression. Variables with a P-value of less than or equal to 0.2 were included in an initial multiple logistic regression model. The final multivariable model included all variables with a P value of less than 0.05.

To better understand the most current practice patterns, multiple logistic regression analysis of provincial use of LC in the final year of the study was also performed, controlling for demographic, clinical and system predictor variables.

Associations were reported as odds ratio (OR) for univariate and adjusted OR for multivariate analyses with 95% confidence interval (95% CI) and P value for each OR. All analyses were conducted with STATA 14® StataCorp. 2015. *Stata Statistical Software: Release 14.* College Station, TX: StataCorp LP.

Results

Across nine provinces, CIHI DAD data identified 105,302 records of patients who underwent colectomy for colon carcinoma between fiscal years 2004 and 2014. Applying the exclusion criteria yielded 63,504 records (Figure 1); 19,691 (31.1%) underwent LC and 43,813 (68.9%) OC.

The overall use of LC and OC in Canada from 2004 to 2014 is depicted in Figure 2. Over that time period, the number of patients undergoing colectomy (LC or OC) for colon cancer increased from 5,601 in 2004 to 5,976 in 2014. The annual proportion of patients undergoing LC increased from 9.2% in 2004 to 51.5% in 2014; absolute number of patients undergoing LC were 513 and 3,080 respectively. The increase in LC over time appeared linear, with an average annual percentage change of 4.2%. By 2014, the majority of Canadian colon cancer patients underwent LC.

Patient, system and demographic characteristics of LC and OC groups are presented in Table 1. Although statistically significant due to large cohort size, some of the differences in demographic, clinical, and system factors were modest. On univariate analysis, LC was more commonly used in urban patients, those treated at high volume hospitals and by high volume surgeons, and among patients undergoing right hemicolectomy.

There were considerable differences in the proportional use of LC between provinces over the study period, ranging from 7.6% in Newfoundland to 36.9% in Ontario (Table 1; Figure 3). The annual number of patients undergoing LC and OC and the annual proportional use of LAC for each province are presented in Appendix B (online only). Newfoundland had the lowest uptake of LC with a mean annual percent change of 0.6% per year, such that only 11.2% of Newfoundland patients were treated laparoscopically in 2014. The greatest increase in the proportional use of LC was observed in Prince Edward Island, increasing from 1.9% in 2004 to 43.1% in 2014. An overall average annual percent change of 4.7% was seen in Ontario, with a particularly steep increase of 9.5% in 2005. In 2014, a full 59.4% of elective colon cancer

patients in Ontario underwent LC. The highest average annual percent change (5.3%) was observed in British Columbia, with 60.2% of patients undergoing LC in 2014. By 2014, the majority of elective colon cancer patients in Alberta underwent LC.

Factors associated with use of LC are presented in Table 2. Adjusted analyses demonstrate year of surgery to be the strongest predictor of LC: 2014 patients were 9.3 times more likely to undergo LC than 2004 patients. Adjusted provincial differences were also substantial, with Newfoundland patients 86.0% less likely to undergo LC than Ontario patients. Urban residence, younger age, high surgeon and high hospital volume were significantly associated with increased likelihood of LC, whereas male sex, medical comorbidities, age older than 80 years and left sided and multisegment resection were associated with lower likelihood of LC. In order to represent the most current provincial practice patterns, we performed a sub analysis limited to 2014 (Table 3). This demonstrated that, compared to the overall study period, odds of LC in 2014 were significantly higher for Prince Edward Island, modestly higher for Alberta and British Columbia, somewhat lower for Manitoba and Nova Scotia and unchanged for Newfoundland, New Brunswick and Saskatchewan.

Discussion

This study represents the first pan-Canadian population-based description and analysis of the use of LC in Canada, and demonstrated that the proportion of LC increased in nine Canadian provinces from 9.2% in 2004 to 51.5% in 2014. The study period covers the decade following publication of seminal randomized trials establishing oncologic equivalence and short term outcome advantages of LC (5-8). The magnitude of the increase in LC observed in Canada was

comparable to that observed in the United Kingdom, the Netherlands, and the United States where LC rates increased to 48% (2014), 61% (2014) and 54% (2012) respectively. (11,18,19). We also observed significant interprovincial variations in the annual use and uptake of LC. Regional variation of LC has been described in other countries; between 2009 and 2010 LC rates ranged from 0% to 96% among 90 hospitals in the Netherlands and from 0% to 67% across 306 hospital referral regions in the US (19,20).

In preference sensitive care, where more than one acceptable treatment modality is available for a given condition, surgeon preference is an important determinant of variation (21). Surgeon preference in turn is primarily guided by training and experience, as well as institutional culture and beliefs. In Canada, survey data suggest that surgeons who perform LC are more likely to have recently entered practice, have completed a minimally invasive surgery fellowship, and / or be affiliated with a university (22). This may reflect the wider adoption of minimally invasive surgery in training institutions across Canada, with subsequent increased exposure of trainees to advanced laparoscopic procedures (23).

Practicing surgeons face unique challenges to the adoption of new surgical techniques. These include limited time to attend training courses, pressure on OR resources and availability of an experienced mentor. Training models traditionally used by practicing surgeons include intensive short (weekend) courses, hands-on conferences and reviewing instructional videos (24). Courses that are supplemented by a mentorship program have been shown to be more effective at introducing advanced laparoscopic procedures in community practice. Such programs usually imply one-on-one mentoring in the OR but can also include centralized and telementoring. However, all these models are time and resource intensive for both trainee and mentor and are

rare in Canada. A more feasible, organic mentorship may ensue when a fellowship trained minimally invasive surgeon joins an established community surgery practice (25).

There are several limitations to our study. Several clinical variables were not available in the DAD maintained by CIHI (e.g. body mass index, tumour stage, local recurrence vs. primary tumour, prior abdominal operation) and thus we are unable to examine their association with LC use. In addition, we were not able to distinguish between the various types of LC (e.g. completely laparoscopic, laparoscopic assisted, laparoscopic converted to open); therefore, LC in this study should be interpreted as a procedure that was at least initiated laparoscopically. The lack of inclusion of Quebec in CIHI DAD may limit the generalizability of the study findings to this province. Finally, the potential impact of health policy and /or health services organization factors such as funding for LC and surgeon reimbursement models for LC were not examined in our study.

Conclusion

Use of LC for colon cancer has increased significantly in Canada since the initial publication of seminal randomized trials. However, significant interprovincial variation in the use of LC was identified, not completely explained by examined patient, system and demographic factors. These data should serve as a baseline for the monitoring of LC uptake in Canada, and suggest potential targets for strategies aimed at increasing LC use.

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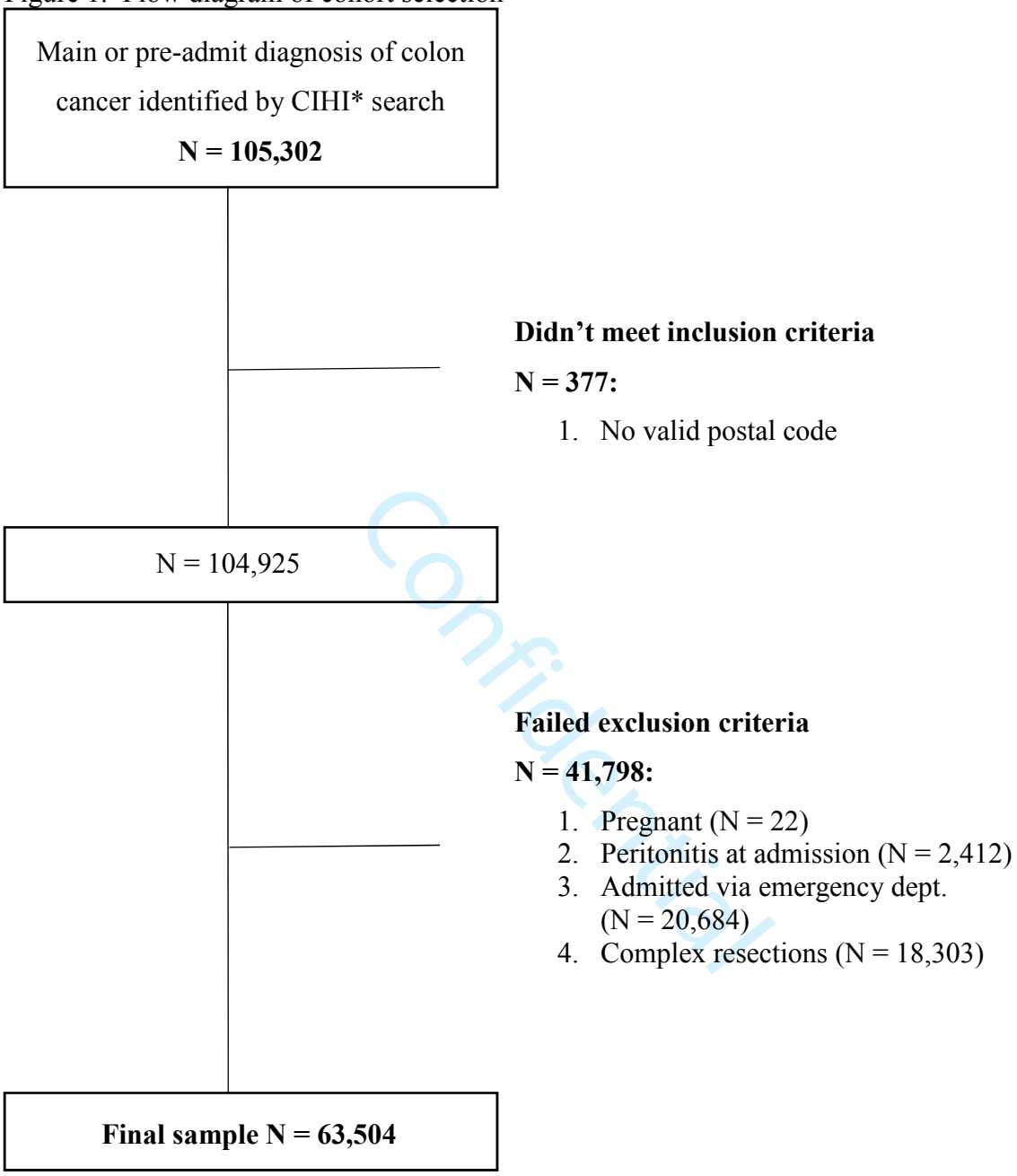
Figure 1. Flow diagram of cohort selection



*Canadian Institute for Health Information

Figure 2. Overall, OC and LC numbers in Canada, 2004-2014

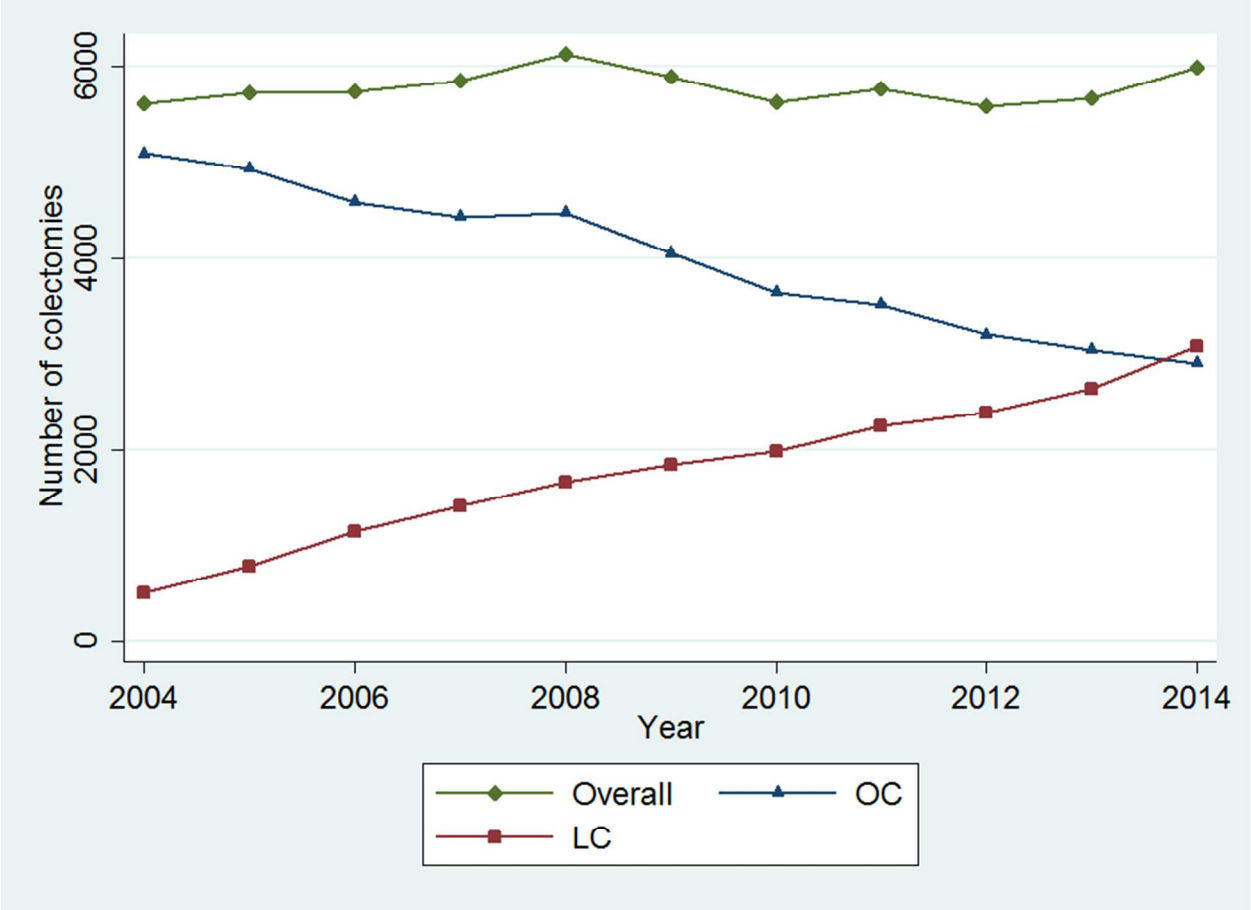
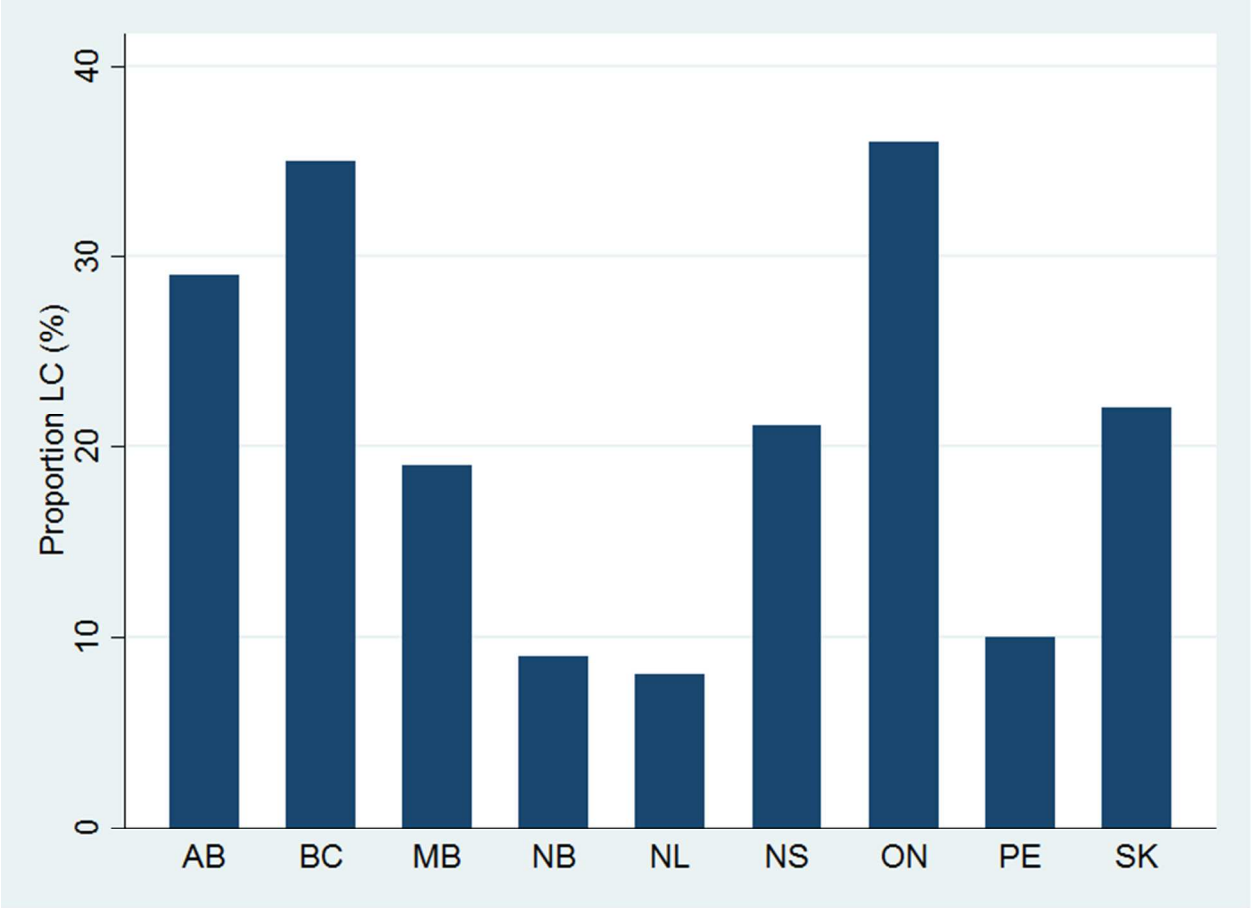


Figure 3. Proportion of LC by province



AB Alberta
BC British Columbia
MB Manitoba
NB New Brunswick
NL Newfoundland
NS Nova Scotia
ON Ontario
PE Prince Edward Island
SK Saskatchewan

Table 1. Demographic, patient and system characteristics of patients undergoing LC and OC

Variable	Laparoscopic (N = 19,691)	Open (N = 43,813)	p-value
Age in years: mean (SD*)	69 (12)	70 (12)	<0.001
Gender: N (%)			<0.001
Male	10,416 (53)	24,158 (55)	
Female	9,275 (47)	19,655 (45)	
Elixhauser comorbidity score: N (%)			0.04
0	12,854 (65)	28,176 (64)	
1-3	6,714 (34)	15,297 (35)	
>3	123 (1)	340 (1)	
Residence: N (%)			<0.001
Rural	3,253 (17)	10,560 (24)	
Urban	16,438 (84)	33,253 (76)	
Surgeon volume: N (%)			<0.001
Low: 1-7	5,771 (29)	17,681 (40)	
High: 7.09 – 37.27	13,920 (70)	26,132 (59)	
Hospital volume: N (%)			<0.001
Low: 1-36.63	5,292 (26)	20,118 (45)	
High: 37.36-102.81	14,390 (73)	23,713 (54)	
Resection type: N (%)			<0.001
Right hemicolectomy	10,004 (51)	19,902 (45)	
Left hemicolectomy	5,809 (30)	12,200 (28)	
Anterior resection	2,706 (14)	8,403 (19)	
Other	1,172 (6)	3,308 (8)	
Year of surgery: N (%)			<0.001
2004	513 (3)	5,088 (12)	
2005	789 (4)	4,932 (11)	
2006	1,149 (6)	4,577 (11)	
2007	1,410 (7)	4,428 (10)	
2008	1,658 (8)	4,467 (10)	
2009	1,842 (9)	4,048 (9)	
2010	1,982 (10)	3,633 (8)	
2011	2,250 (11)	3,510 (8)	
2012	2,384 (12)	3,199 (7)	
2013	2,634 (13)	3,035 (7)	
2014	3,080 (16)	2,896 (7)	

Table 1 (cont'd)

Variable	**Laparoscopic (N = 19 691)**	**Open (N = 43,813)**	**p-value**
Province: N (%)			<0.001
Newfoundland	172 (1)	2,059 (5)	
Prince Edward Island	49 (0.3)	454 (1)	
Nova Scotia	636 (3)	2,348 (5)	
New Brunswick	196 (1)	1,958 (5)	
Ontario	11,506 (58)	20,088 (46)	
Manitoba	623 (3)	2,740 (6)	
Saskatchewan	549 (3)	1,946 (4)	
Alberta	1,949 (10)	4,731 (11)	
British Columbia	4,011 (20)	7,489 (17)	

*SD: Standard Deviation

Table 2. Simple and multiple logistic regression of factors associated with LC

Variable	Univariate OR* (95% CI†)	Univariate p-value	Multivariate Adjusted OR* (95% CI†)	Multivariate p-value
Year, 2014 relative to 2004	7.55 (7.12-8.00)	<0.001	9.31 (8.60-10.09)	<0.001
Female sex (reference)	1.00		1.00	
Male sex	0.92 (0.88-0.95)	<0.001	0.94 (0.90-0.98)	<0.001
Age in years				
66-80 (reference)	1.00		1.00	
18-50	1.19 (1.11-1.28)	<0.001	1.15 (1.07-1.24)	<0.001
51-65	1.11 (1.06-1.15)	<0.001	1.14 (1.09-1.19)	<0.001
>80	0.93 (0.89-0.98)	0.01	0.87 (0.83-0.92)	<0.001
Province				
Ontario (reference)	1.00		1.00	
Newfoundland	0.12 (0.10-0.14)	<0.001	0.14 (0.12-0.16)	<0.001
New Brunswick	0.15 (0.13-0.17)	<0.001	0.16 (0.14-0.19)	<0.001
Prince Edward Island	0.14 (0.11-0.20)	<0.001	0.23 (0.17-0.32)	<0.001
Manitoba	0.36 (0.33-0.39)	<0.001	0.39 (0.36-0.43)	<0.001
Saskatchewan	0.42 (0.38-0.46)	<0.001	0.54 (0.49-0.60)	<0.001
Nova Scotia	0.44 (0.40-0.48)	<0.001	0.53 (0.48-0.59)	<0.001
Alberta	0.64 (0.60-0.67)	<0.001	0.57 (0.53-0.60)	<0.001
British Columbia	0.86 (0.82-0.90)	<0.001	0.89 (0.85-0.93)	<0.001
Residence				
Rural (reference)	1.00		1.00	
Urban	1.68 (1.61-1.76)	<0.001	1.24 (1.18-1.30)	<0.001
Elixhauser score				
0 (reference)	1.00		1.00	
1-3	0.88 (0.85-0.92)	<0.001	0.90 (0.87-0.94)	<0.001
4-8	0.76 (0.61-0.94	0.01	0.79 (0.63-0.98)	0.04
Hospital volume				
Low (reference)	1.00		1.00	
High	2.44 (2.35-2.54)	<0.001	2.04 (1.96-2.13)	<0.001
Surgeon volume				
Low (reference)	1.00		1.00	
High	1.65 (1.59-1.71)	<0.001	1.29 (1.24-1.35)	<0.001
Resection type				
Right (reference)	1.00		1.00	
Left	0.97 (0.93-1.01)	0.20	0.91 (0.87-0.95)	<0.001
Anterior	0.75 (0.70-0.81)	<0.001	0.58 (0.55-0.62)	<0.001
Other	0.66 (0.63-0.70)	<0.001	0.71 (0.66-0.76)	<0.001

*OR: Odds ratio

†CI: Confidence Interval

Table 3. Logistic regression of association of provinces with LC, 2014

Province	**Multivariate Adjusted[*] OR[†] (95% CI[∞])**	**Multivariate p-value**
Ontario (reference)	1.00	
Newfoundland	0.09 (0.06-0.14)	<0.001
New Brunswick	0.18 (0.13-0.26)	<0.001
Prince Edward Island	0.80 (0.48-1.34)	0.40
Manitoba	0.30 (0.22-0.38)	<0.001
Saskatchewan	0.51 (0.39-0.68)	<0.001
Nova Scotia	0.33 (0.25-0.44)	<0.001
Alberta	0.68 (0.57-0.81)	<0.001
British Columbia	1.10 (0.92-1.22)	0.46

*Adjusted for sex, age, rural / urban residence, Elixhauser score, hospital volume, surgeon volume and resection type

[†]OR: Odds Ratio

[∞]CI: Confidence Interval

Appendix A. Codes for exclusion criteria

Diagnostic codes (ICD-10-CA)*:		N
Z32.1	Pregnancy confirmed	22
K65.0	Peritonitis	2,412
Institution from type (CIHI DAD† field code):		
E	Emergency room	20,684
Intervention codes for complex resections (CCI∞):		
1.MG.87.^^	Lymphadenectomy some intra abdominal nodes	1,558
1.MG.89.^^	Lymphadenectomy, intra abdominal nodes with surrounding tissue, retroperitoneal dissection	130
1.NF.87.^^	Excision partial, stomach	301
1.NF.89.^^	Excision total stomach	6
1.NF.90.^^	Excision total with reconstruction stomach	4
1.NF.91.^^	Excision radical stomach, with reconstruction	19
1.NP.86.^^	Closure of fistula, large and small intestine	119
1.OA.87.^^	Excision partial liver	607
1.OB.87.^^	Excision partial, spleen	46
1.OB.89.^^	Excision total spleen	321
1.OJ.87.^^	Excision partial pancreas	84
1.OK.87.^^	Excision partial pancreas + duodenum	37
1.OK.89.^^	Excision total pancreas + duodenum	1
1.OK.91.^^	Excision radical pancreas + duodenum	4
1.OT.07.^^	Hyperthermy abdominal cavity	43
1.OT.35.^^	Pharmacotherapy local abdominal cavity	115
1.OT.52.^^	Drainage abdominal cavity	1,867
1.OT.72.^^	Adhesiolysis	4,850
1.OT.87.^^	Excision partial abdominal cavity	982
1.OT.91.^^	Excision radical abdominal cavity	88
1.OW.^^.^^	Therapeutic interventions on surgically constructed sites in digestive and biliary tract	306
1.PB.87.^^	Excision partial adrenal gland	14
1.PB.89.^^	Excision total adrenal gland	16
1.PC. 87.^^	Excision partial kidney	43
1.PC. 89.^^	Excision total kidney	66
1.PC. 91.^^	Excision radical kidney	94
1.PG.72.^^	Release ureter	364
1.PG.80.^^	Repair ureter	130
1.PG.82.^^	Reattachment ureter	2
1.PG.87.^^	Excision partial ureter	117
1.PG.89.^^	Excision total ureter	12
1.PM.87.^^	Excision partial bladder	770
1.PM.89.^^	Excision total bladder	4
1.PM.90.^^	Excision total with reconstruction bladder	9

1.PM.91.^^	Excision radical bladder	31
1.PM.92.^^	Excision radical + reconstruction bladder	65
1.PV.^^.^^	Therapeutic interventions on surgically created sites in urinary tract	7
1.RB.87.^^	Excision partial ovary	173
1.RB.89.^^	Excision total ovary	351
1.RD.89.^^	Excision total ovary with fallopian tube	1,535
1.RM.87.^^	Excision partial uterus and surrounding structures	178
1.RM.89.^^	Excision total uterus and surrounding structures	532
1.RM.91.^^	Excision radical uterus and surrounding structures	45
1.RS.87.^^	Excision partial vagina	70
1.SF.87.^^	Excision partial, sacrum and coccyx	2
1.SF.91.^^	Excision radical, sacrum and coccyx	1
1.SL.87.^^	Excision partial, ribs	1
1.SQ.87.^^	Excision partial, pelvis	4
1.SQ.91.^^	Excision radical, pelvis	2
1.SQ.93.^^	Amputation, pelvis	1
1.SY.72.^^	Release, muscles of the chest and abdomen	2
1.SY.80.^^	Repair, muscles of the chest and abdomen	6,650
1.SY.84.^^	Construction or reconstruction, muscles of the chest and abdomen	11
1.SY.87.^^	Excision partial, muscles of the chest and abdomen	39
1.SZ.87.^^	Excision partial, soft tissues of the chest and abdomen	386
1.YS.78.^^	Repair by decreasing size, skin of abdomen and trunk	6
1.YS.87.^^	Excision partial, skin of abdomen and trunk	125
Total complex resections		20,528
Total after considering duplicate cases		18,303

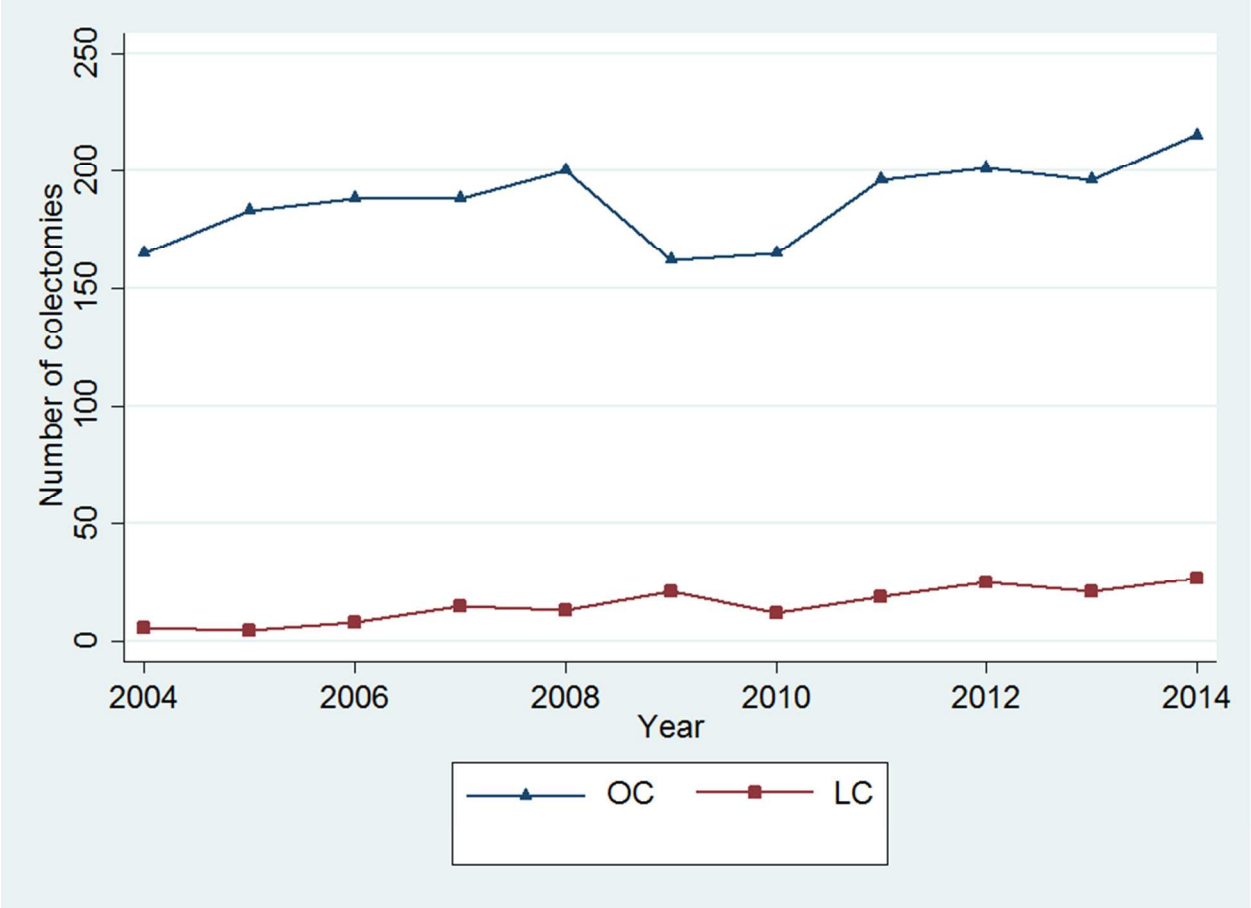
*International Classification of Diseases and Related Health Problems, 10th Revision, Canada

† Canadian Institute for Health Information Discharge Abstract Database

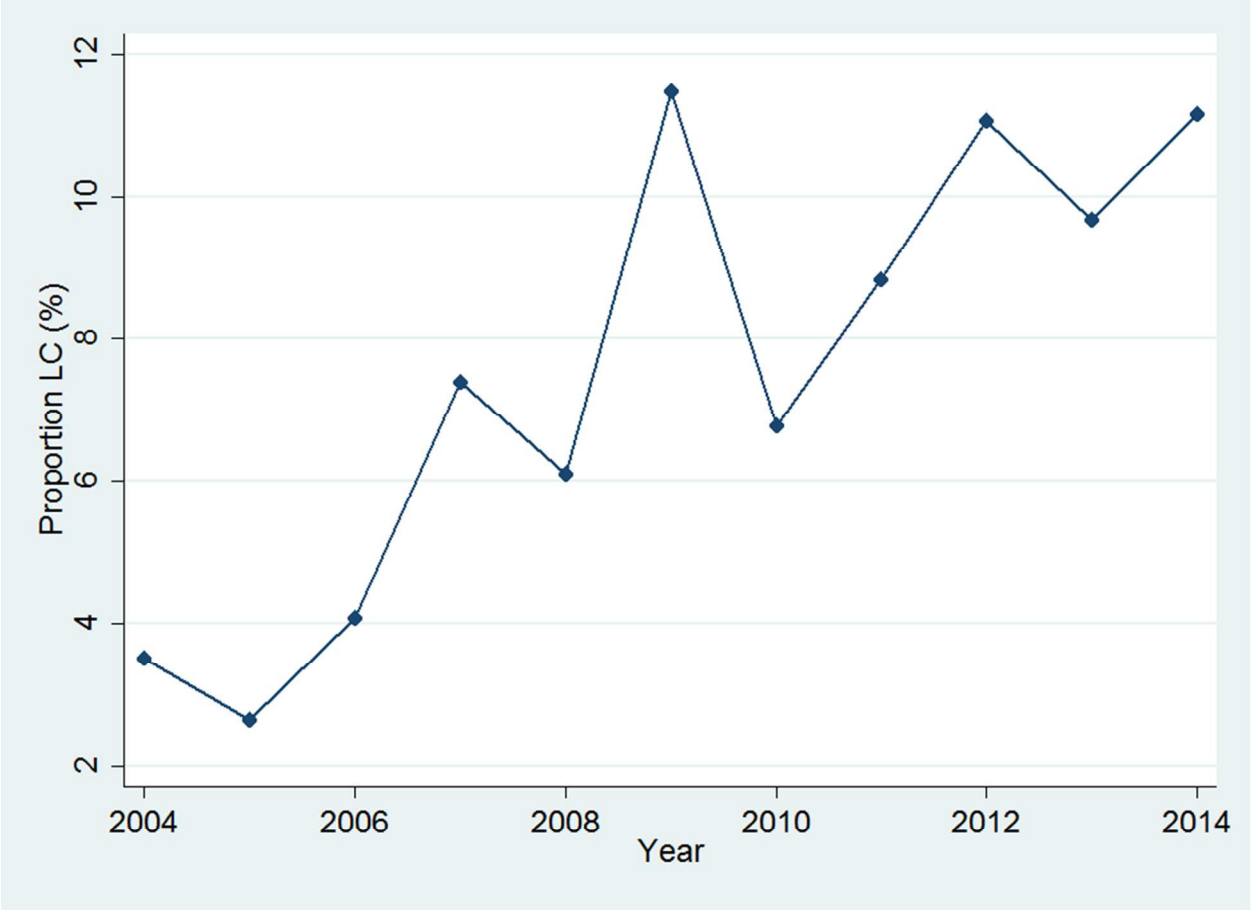
∞ Canadian Classification of Health Interventions

Appendix B. Number of OC and LC and proportional use of LC by province *(online only)*

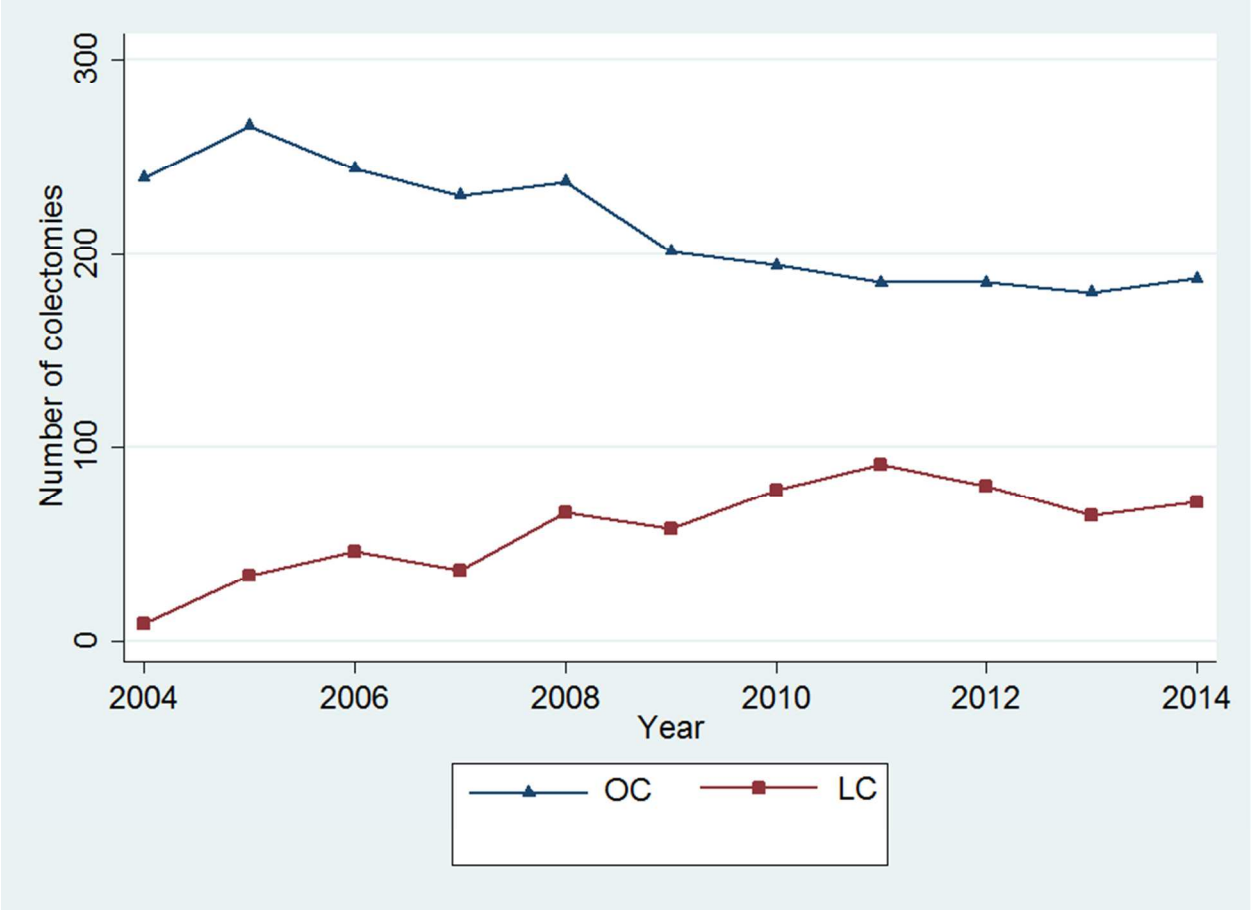
Annual number of OC and LC: Newfoundland



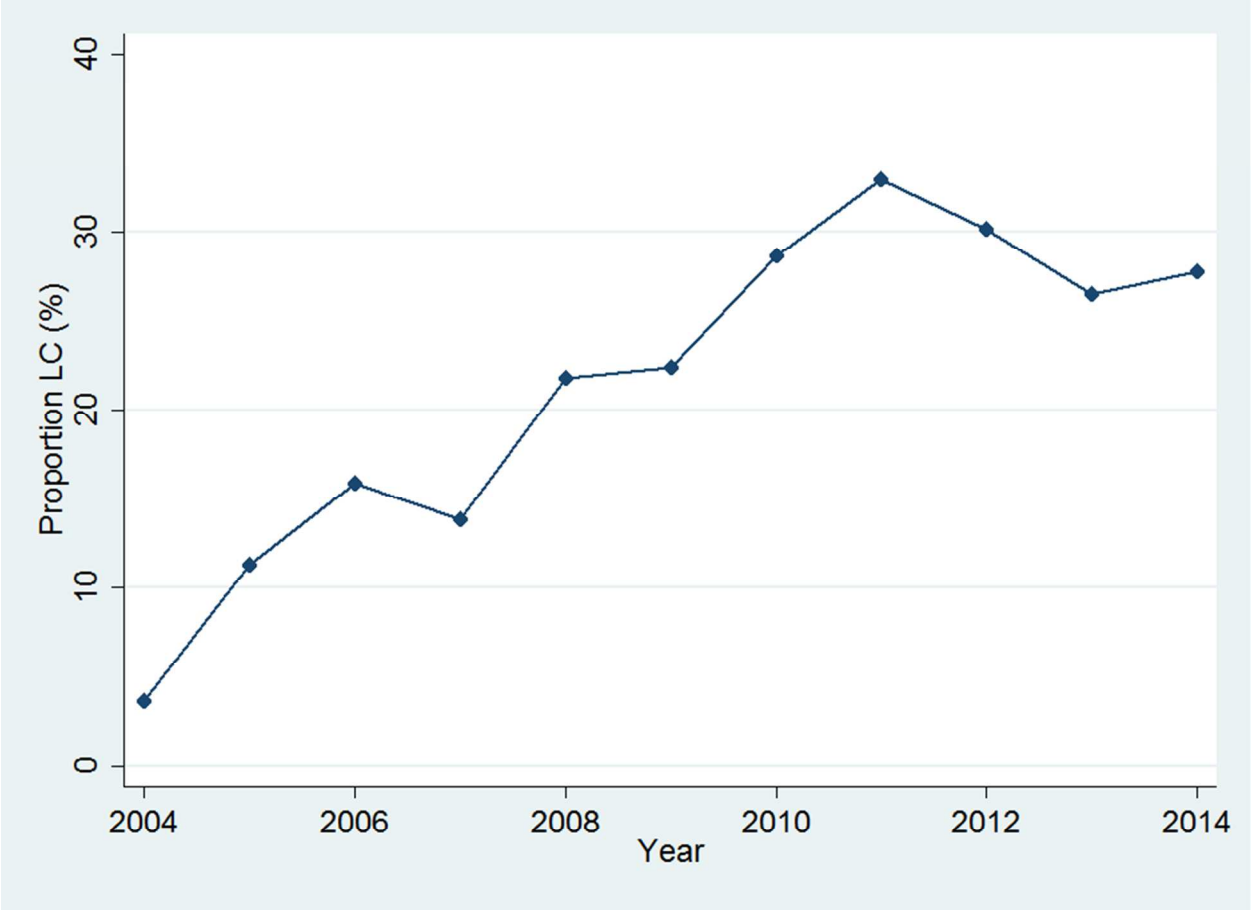
Annual proportional use of LC: Newfoundland



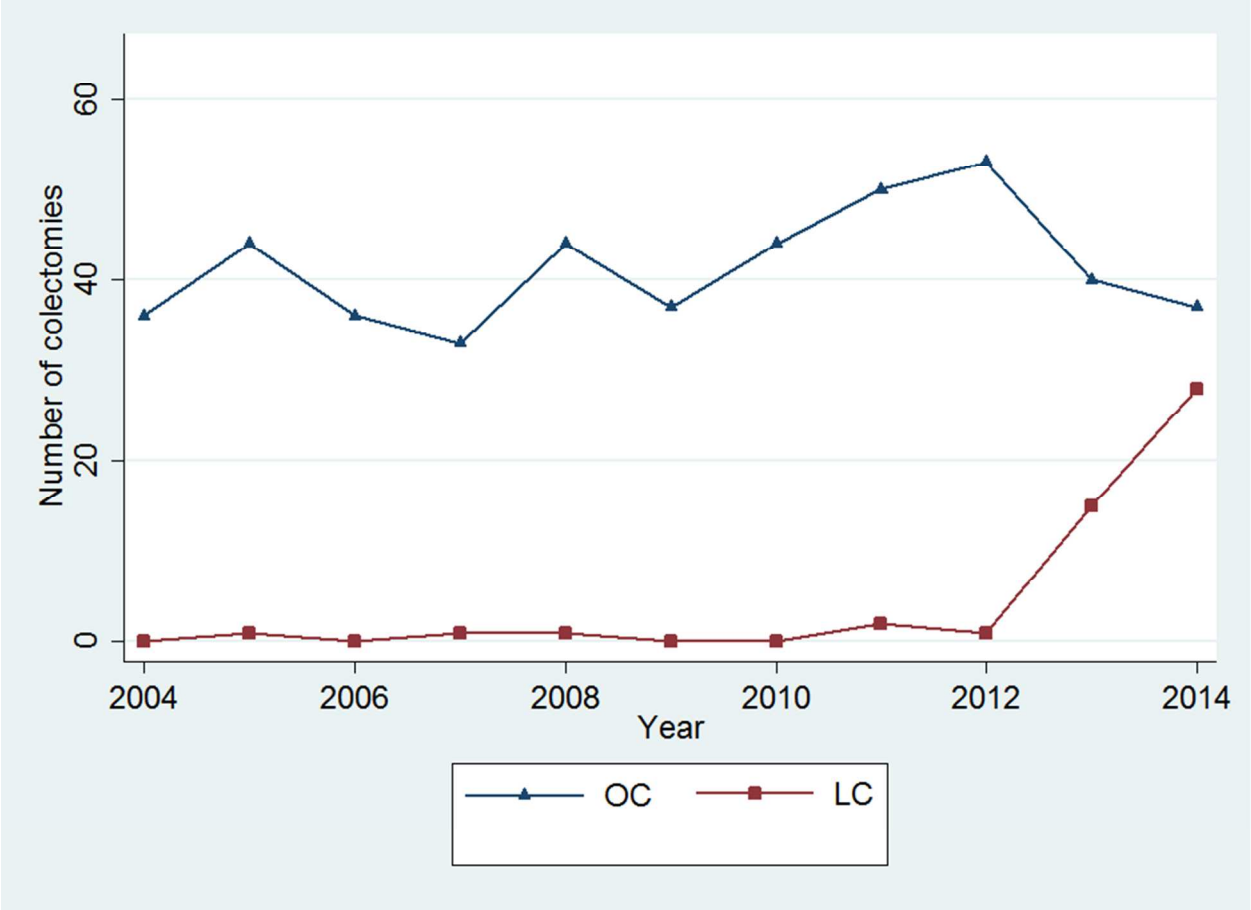
Annual number of OC and LC: Nova Scotia



Annual proportional use of LC: Nova Scotia



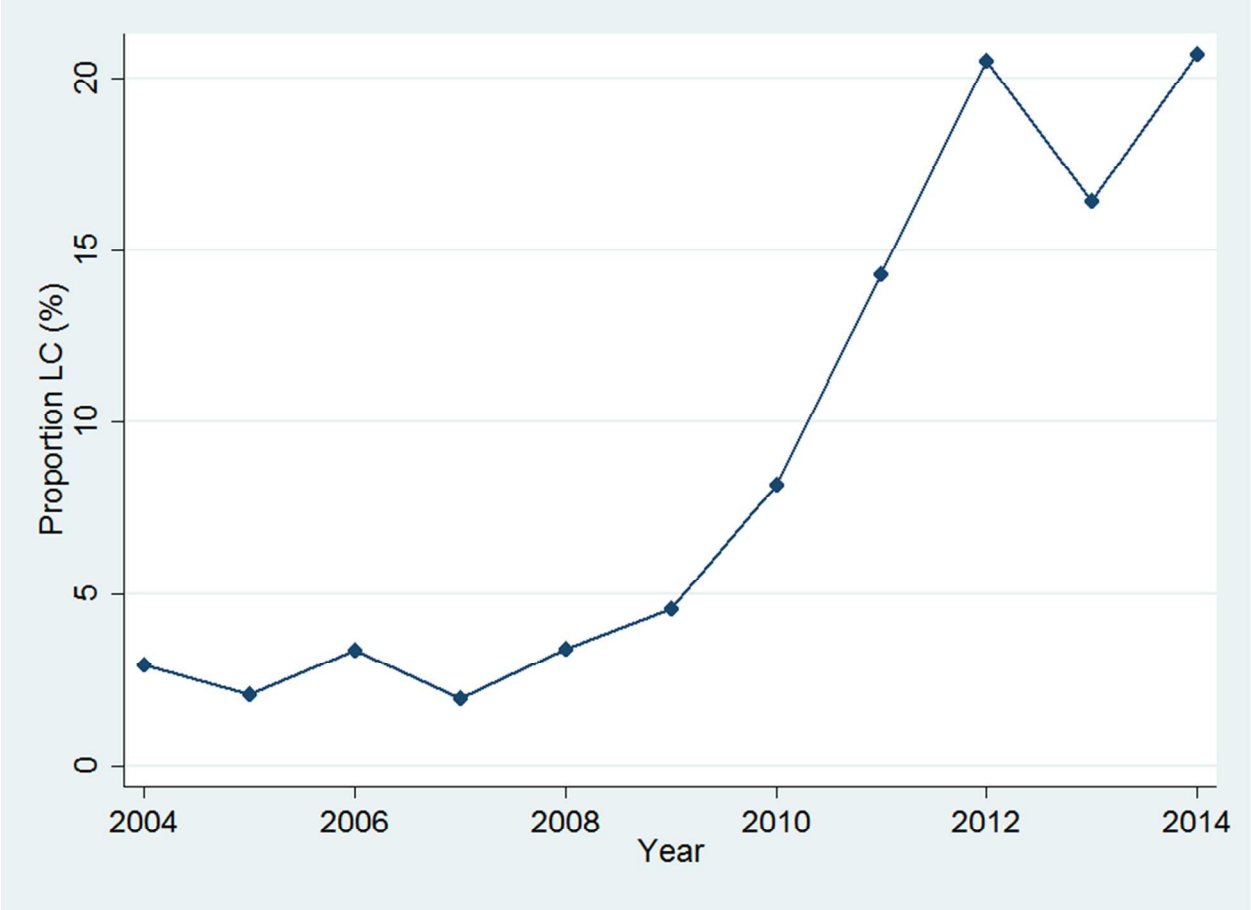
Annual number of OC and LC: Prince Edward Island



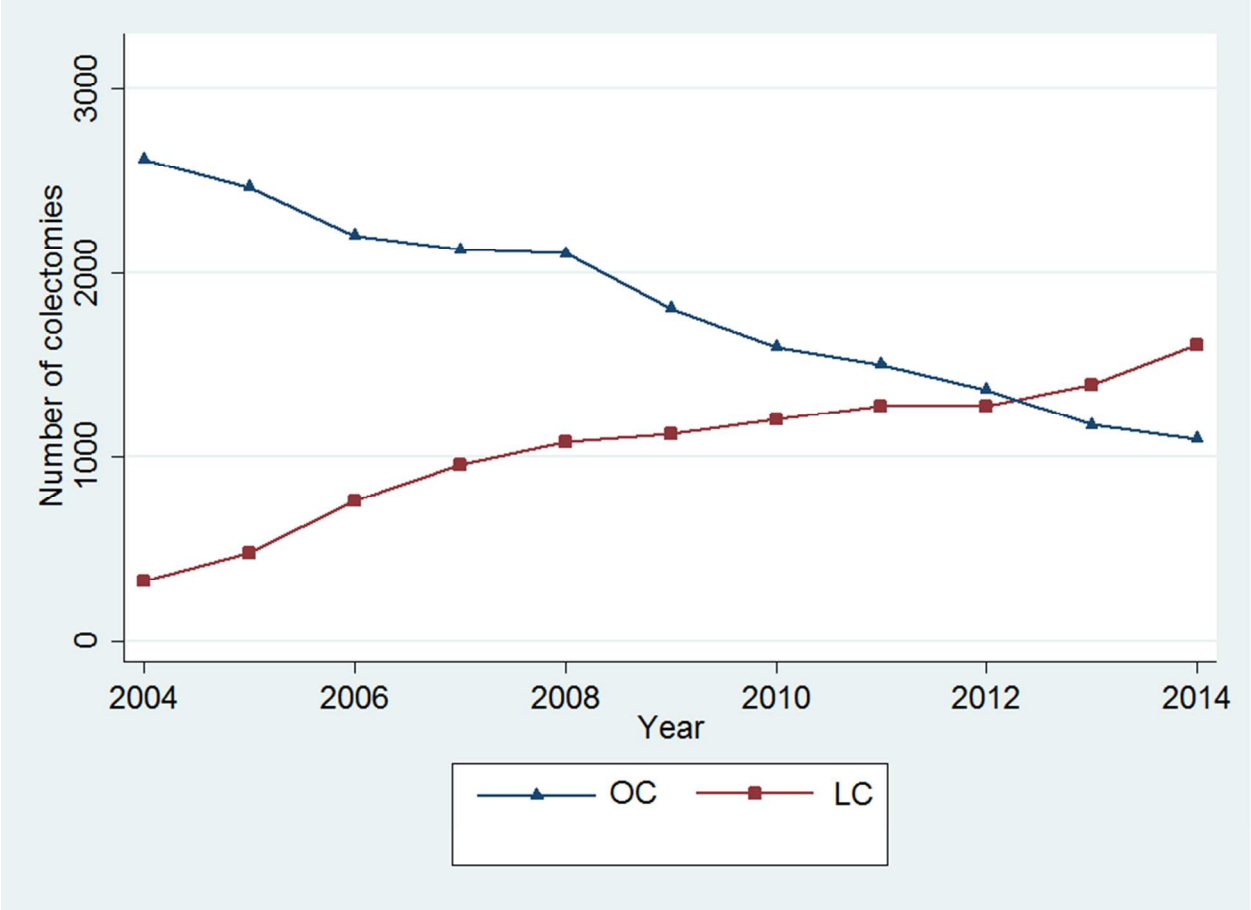
Annual proportional use of LC: Prince Edward Island

Annual number of OC and LC: New Brunswick

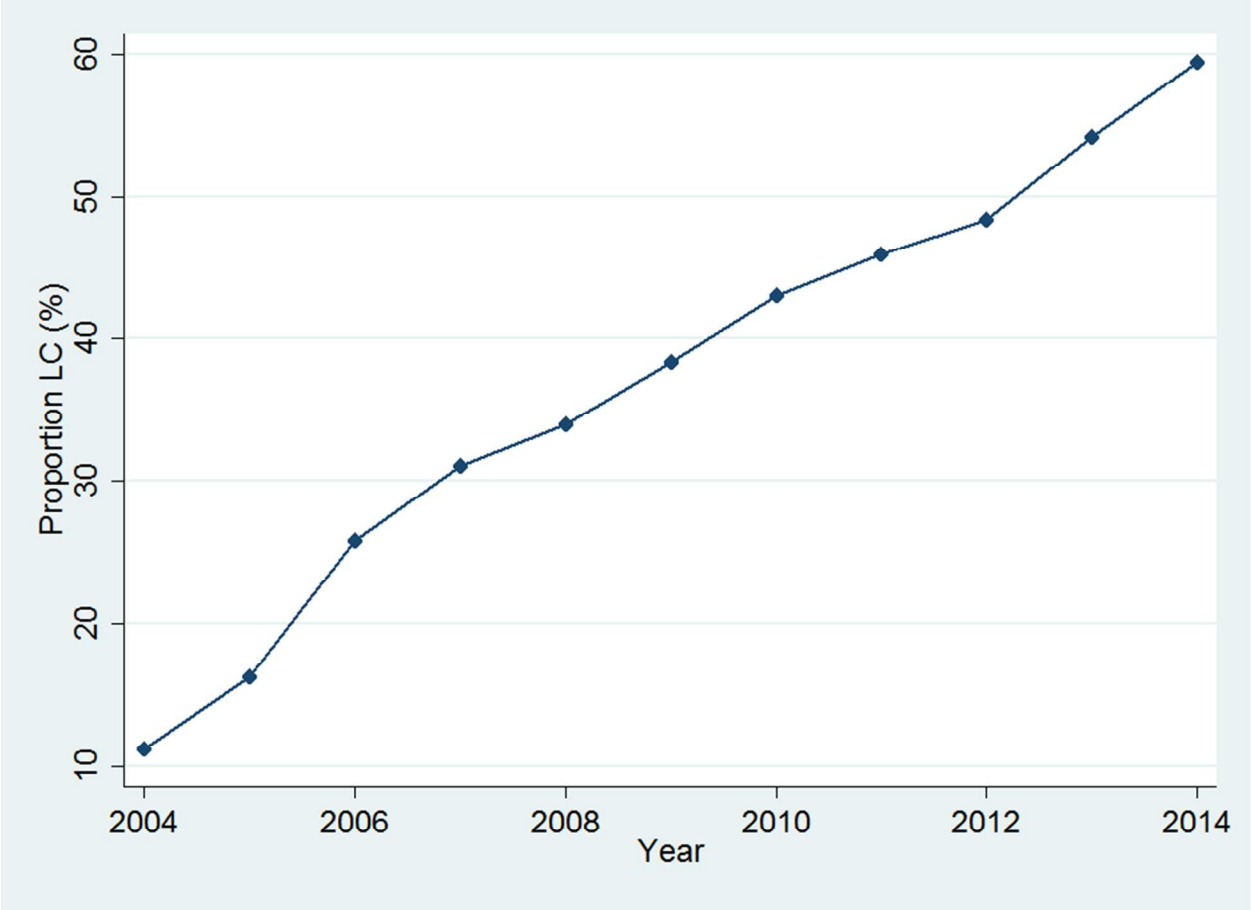
Annual proportional use of LC: New Brunswick



Annual number of OC and LC: Ontario

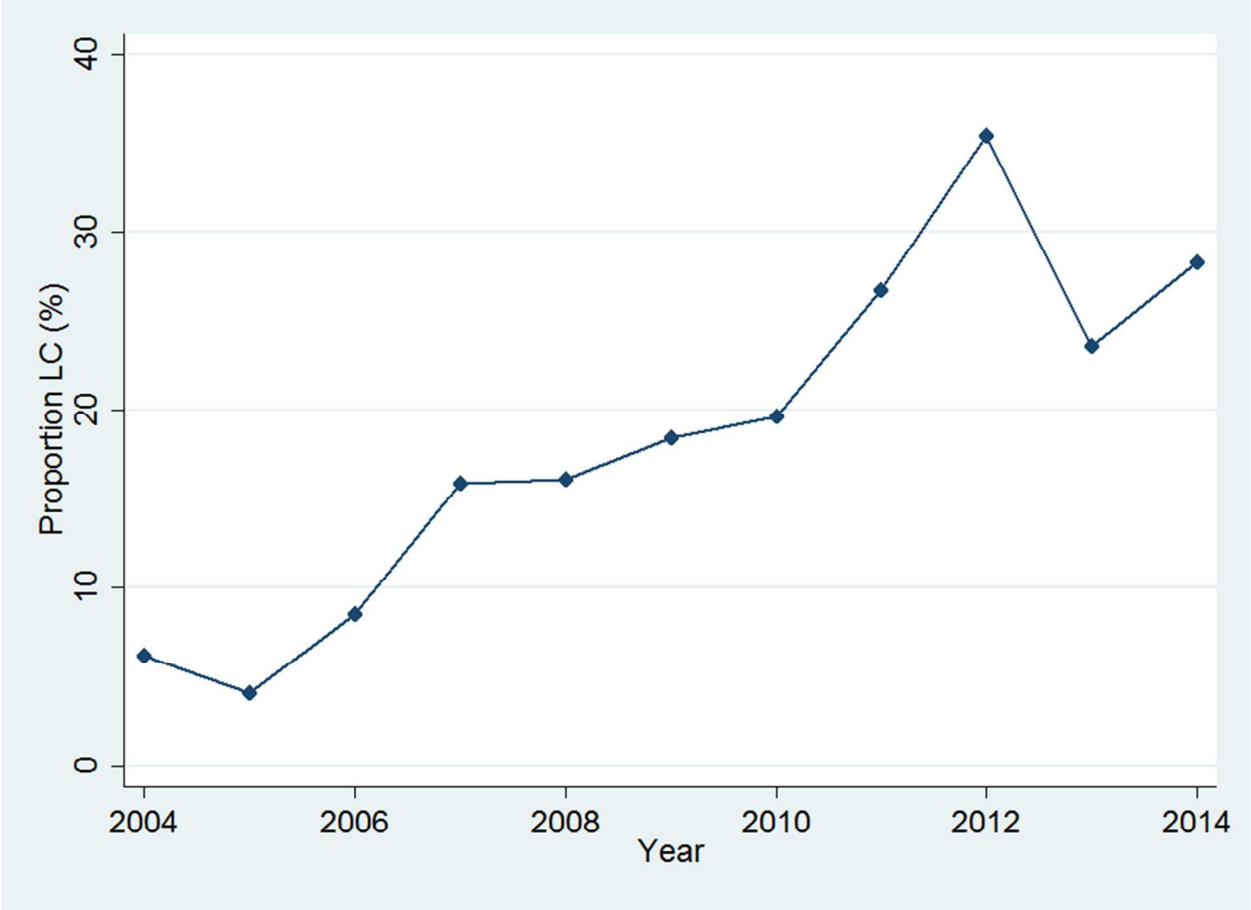


Annual proportional use of LC: Ontario

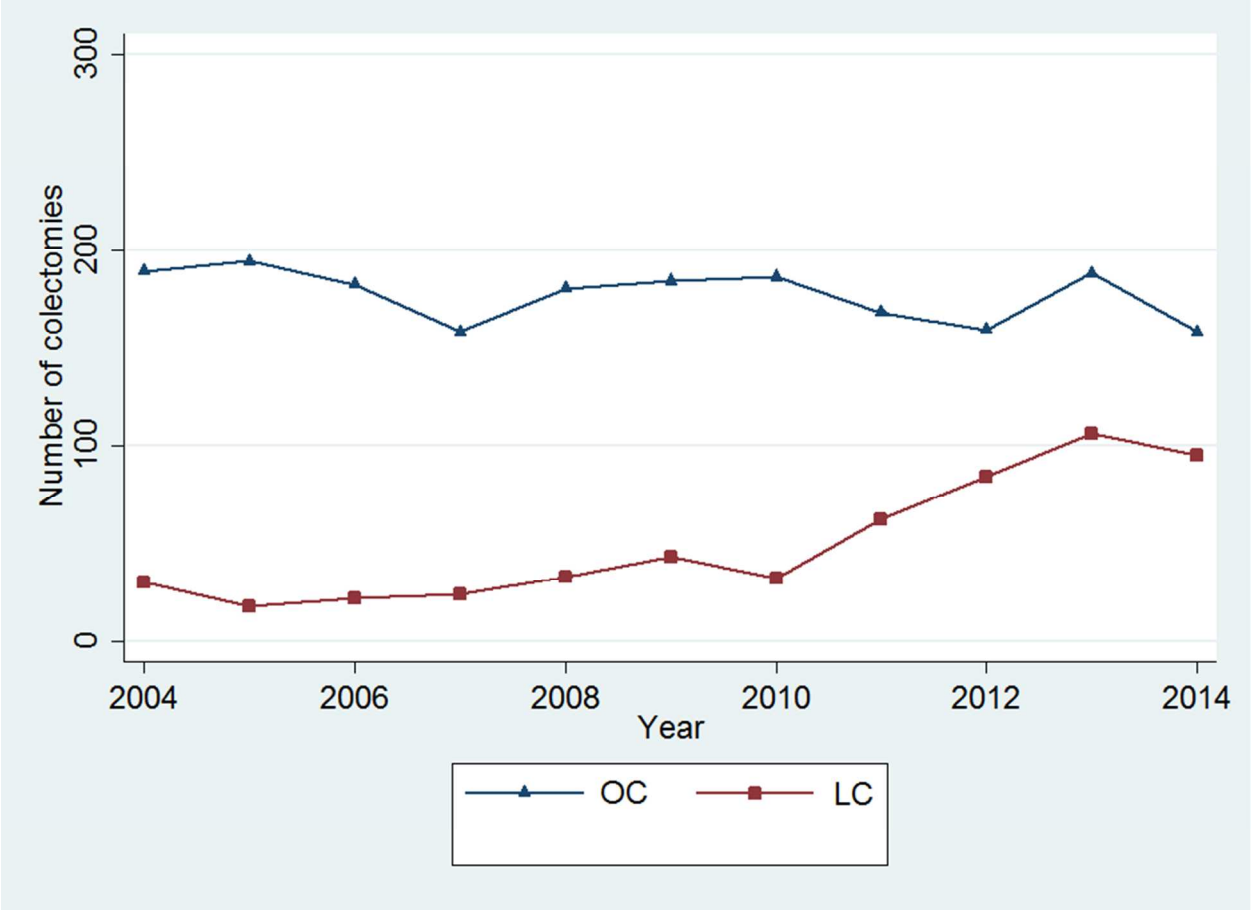


Annual number of OC and LC: Manitoba

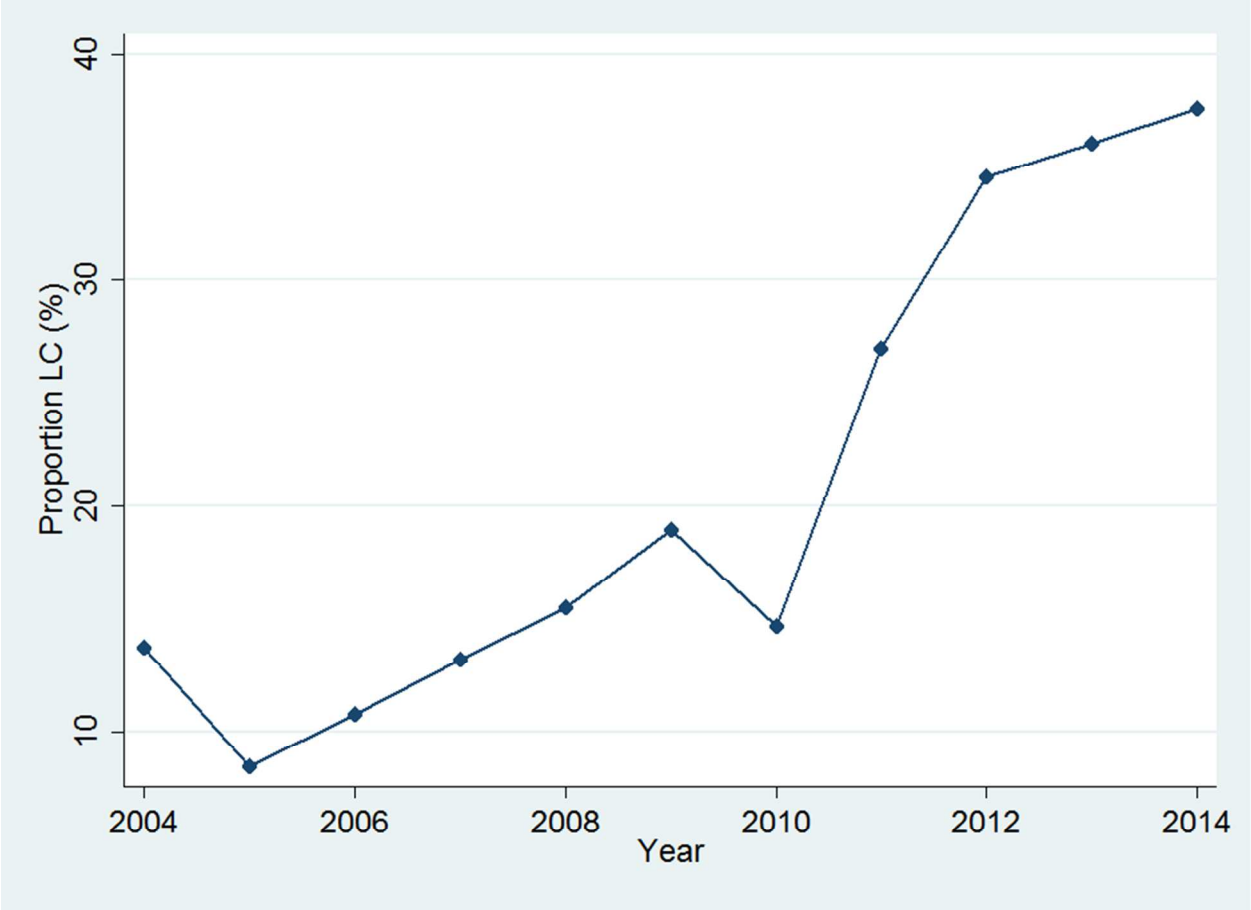
Annual proportional use of LC: Manitoba



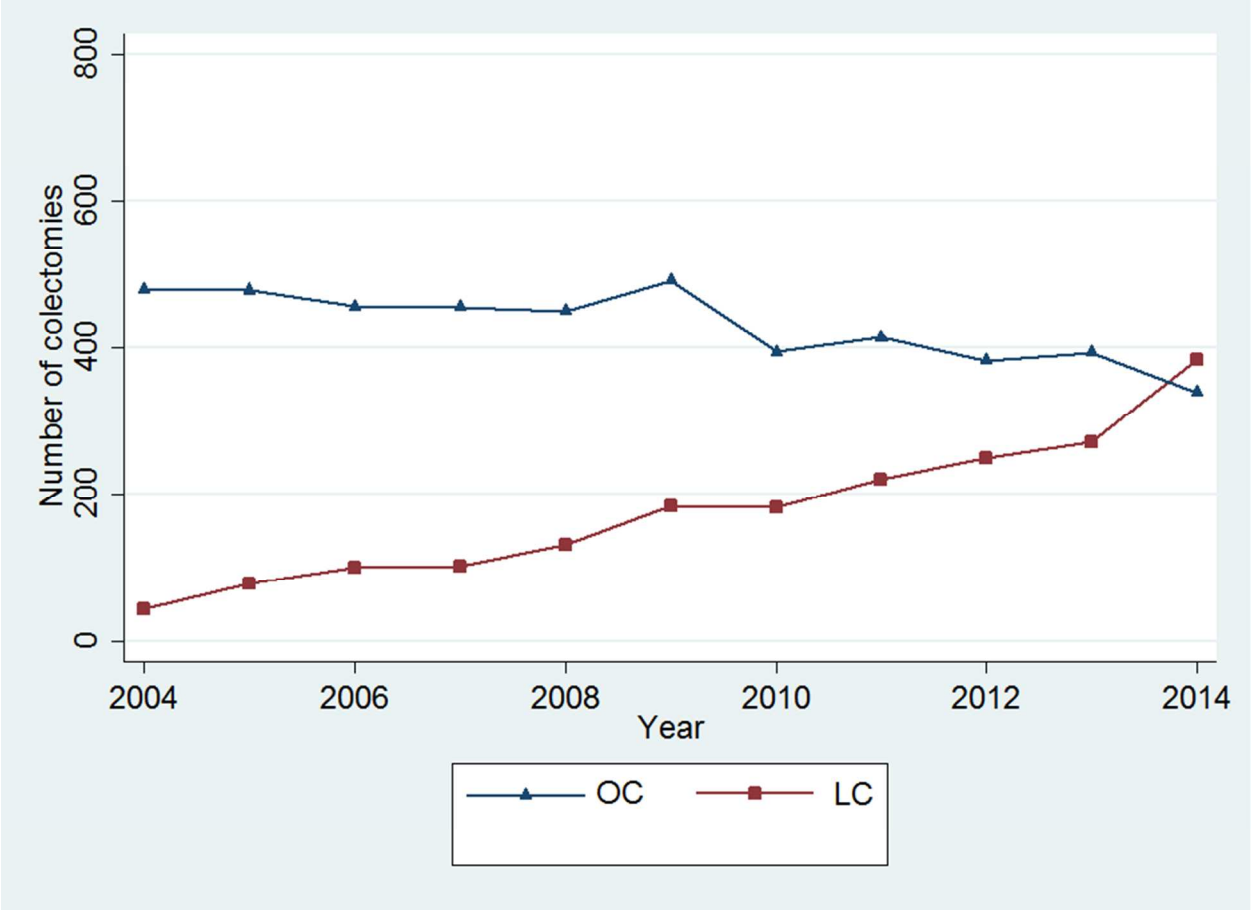
Annual number of OC and LC: Saskatchewan



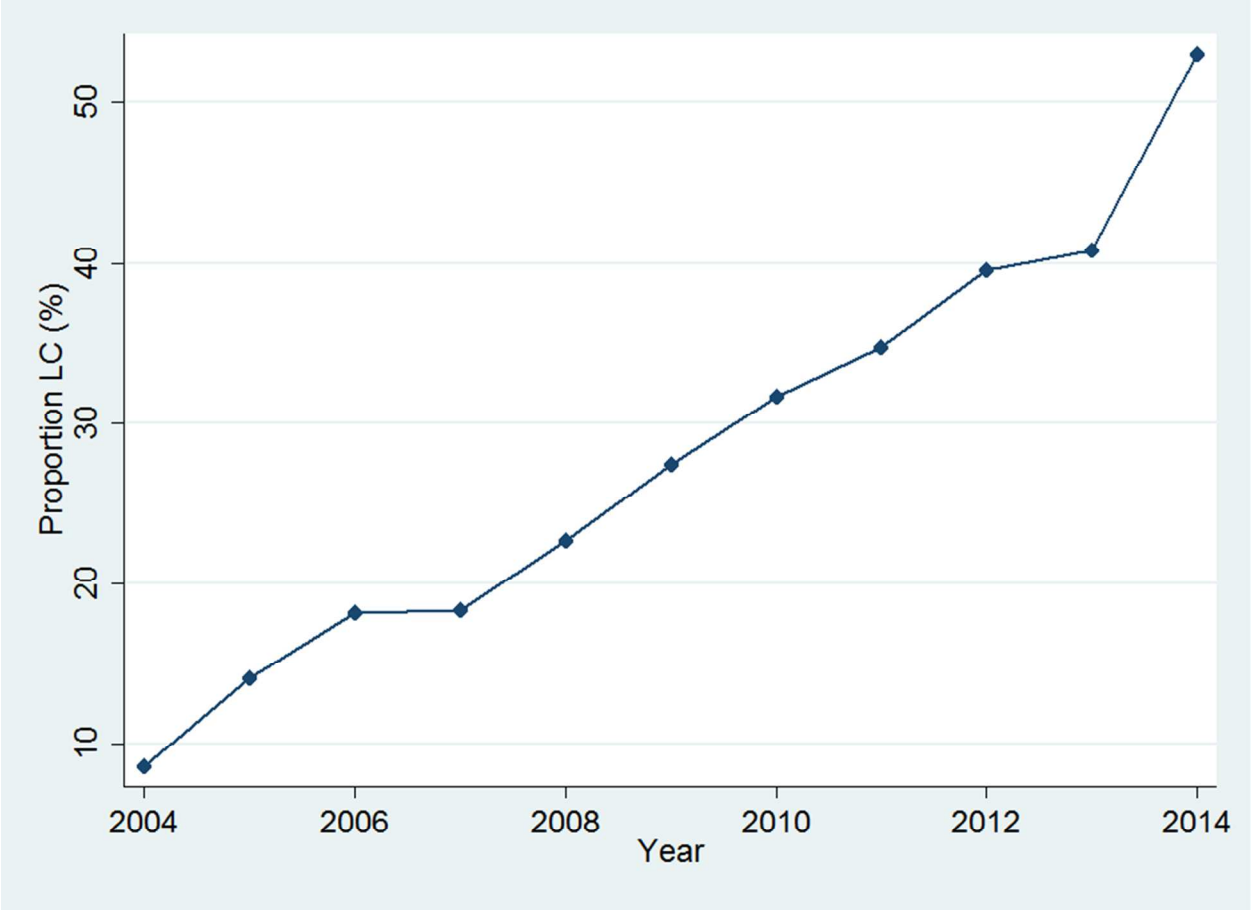
Annual proportional use of LC: Saskatchewan



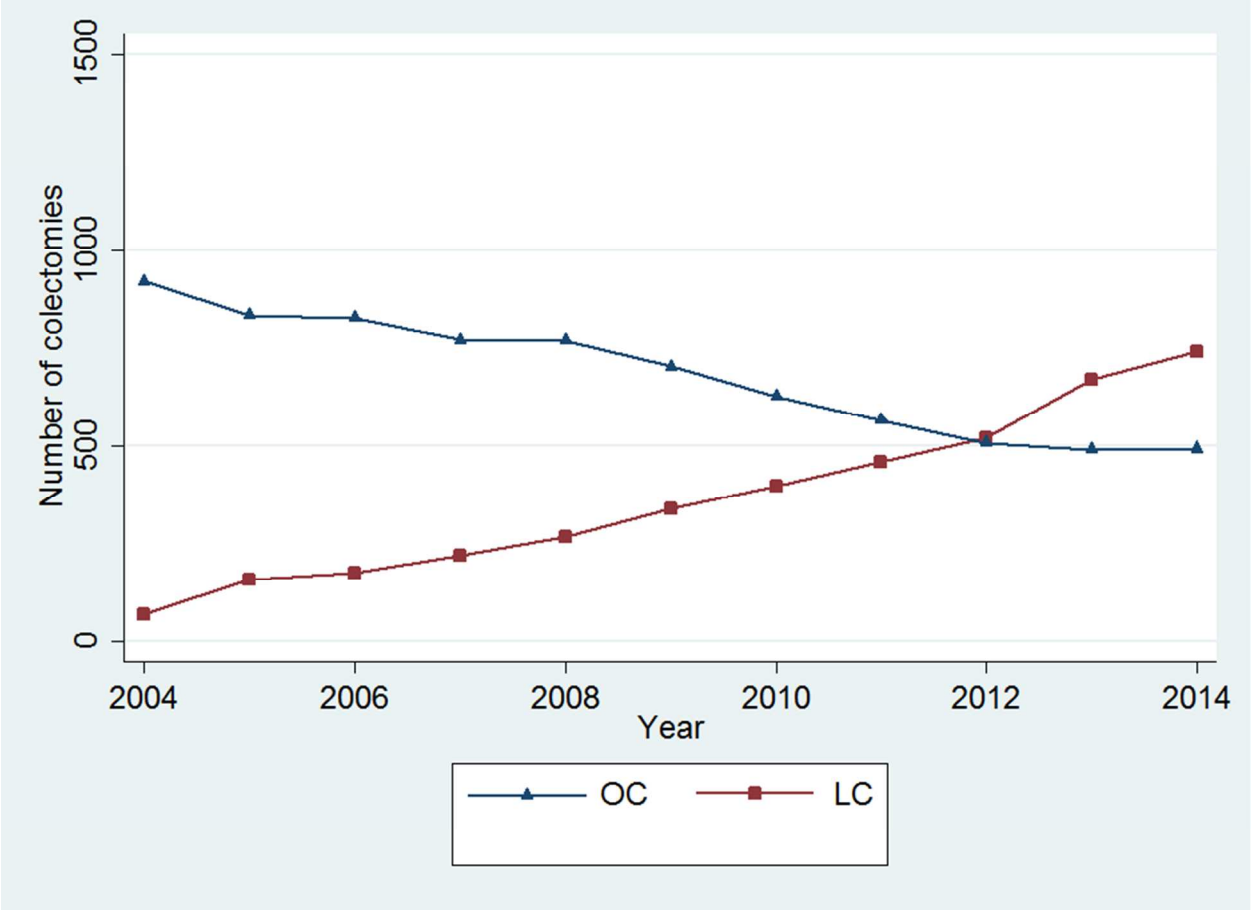
Annual number of OC and LC: Alberta



Annual proportional use of LC: Alberta



Annual number of OC and LC: British Columbia



Annual proportional use of LC: British Columbia