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International Competition, R&D Investment Patterns, and Endogenous Sunk Costs in Canada and the United States, 1987-2002

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International Competition, R&D Investment Patterns, and Endogenous Sunk Costs in Canada and the United States, 1987–2002

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Introduction

The causal relationship between market structure, innovation, and competition intensity has been contested in economic literature, resulting in contradictory empirical estimates of the magnitude, and even the direction, of linkages between competition intensity and research and development (R&D) spending. [1]

This paper contributes to the literature of competition intensity and innovation by using John Sutton's (1998) sunk cost theory to provide empirical evidence as to the impact on R&D investment of competition intensity increases via large scale trade liberalization for countries with heterogeneous

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productivity levels. Holding relative productivity differences between the two countries constant, sunk costs theory predicts that an increase in competition intensity between two countries due to the reduction in trade barriers produces the following effects (in an R&D intensive industry): at first, R&D expenditures in both countries escalate, but eventually the country with higher productivity raises its R&D intensity relative to the second country, for a given industry. This results in firms in the country with lower productivity either dropping out of the industry entirely, or remaining in the industry and concentrating on producing goods that are less R&D intensive and that incorporate less value added. Using a difference-in-difference econometric specification and industry level data for the 1987–2002 period, this study finds empirical evidence of these effects in the period following the North American Free Trade Agreement (NAFTA) between Canada and the United States (US). Although R&D investment increased for both countries in absolute terms, Canadian industries' R&D intensity declined relative to their United States competitors.

The paper proceeds as follows. The first section describes the theory of sunk costs and presents its predictions regarding the impact of an increase in competition intensity on innovation. The second section discusses the econometric model employed and the data used in the estimation process. The third section then presents the results, and the fourth section concludes.

1.1 Competition Intensity and Innovation

The literature of competition intensity and innovation is fraught with contradictory theoretical hypotheses, and inconsistent empirical evidence. Schumpeter (1934) states that monopoly rents create an incentive for firms to invest in innovation, thereby producing a negative relationship between the intensity of market competition and firm innovation. Other models predict the opposite. [2] Yet another set of models finds an unstable "inverted U" relationship between competition intensity and innovation. [3] One of the main reasons for these disparities is that most of the literature fails to account for important methodological issues such as the measurement of competition, [4] or for the inherent endogeneity between market structure, competition intensity and innovation.

Concerns about these issues have led to the development of theories that offer less specific, though more certain, predictions. One such relatively new approach is the game theoretic model of endogenous sunk costs, as developed in Sutton (1991, 1998), which largely avoids causal econometric estimation in favour of robust reduced form relationships that describe the evolution of R&D spending in conjunction with competition intensity and market structure. Sunk cost theory has been proven to be robust for a number of different market types in Sutton (1998), Lyons, Matraves, and Moffat (2001), and Symeonidis (2002).

1.2 Sunk Cost Theory Framework

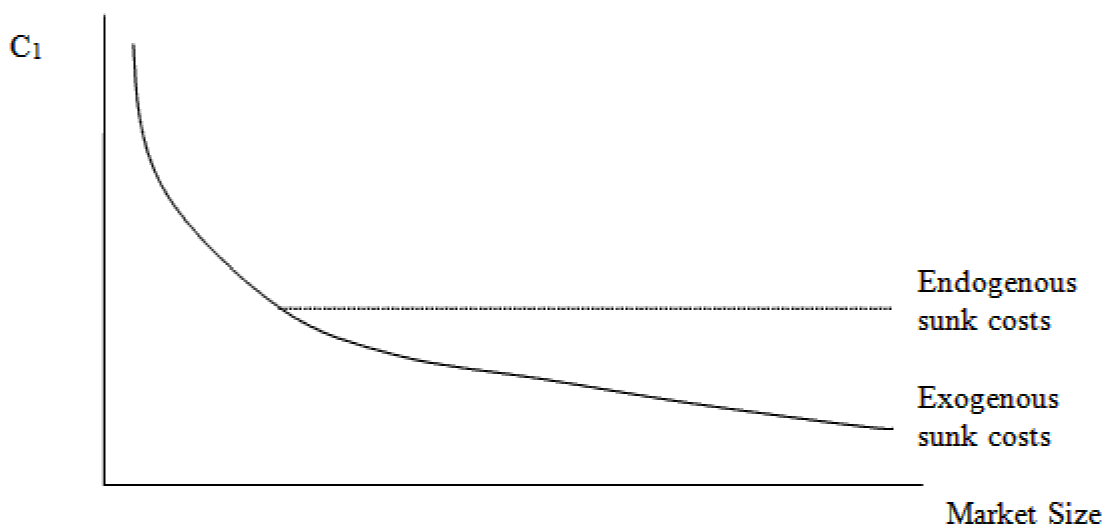
This study adopts the theoretical framework of sunk costs from Sutton (1991, 1998). Sunk cost theory rests on the concept of an equilibrium configuration in a multi-stage oligopoly game played in quantities (a la Cournot) after firms pay an initial sunk cost to enter the market. [5] The equilibrium profits of any firm present in the final stage of the game can be defined as a linear function of market size, and as some function of the number of firms in the market and of the degree of competition intensity. Thus, the equilibrium configuration can be expressed as a condition where the profits of firms that have paid the sunk cost to enter the market must be non-negative and cover their sunk cost of entry, but not so large as to generate new entry in equilibrium.

1.3 Endogenous and Exogenous Sunk Cost Industries:

Sutton (1991) broadly divides industries into "exogenous" and "endogenous" sunk cost industries. Exogenous sunk cost industries have structural characteristics which do not allow for a firm to increase its demand by spending more on demand shifters such as R&D or advertising. Since such an industry does not have significant entry barriers (besides the initial fixed sunk cost), as the market becomes larger the number of firms it can sustain also increases as profits increase proportionally. A strictly negative relationship therefore exists between concentration and market size, and the concentration tends towards zero as market size tends towards infinity.

In endogenous sunk cost industries, however, firms can invest in producing higher value added products (through R&D), or in advertising, and shift their demand outward, increasing their market share. [6] When market size is relatively small, the benefits to investing in demand shifters are also small, and an endogenous sunk cost industry behaves in the same way as an exogenous sunk cost industry in equilibrium. However, as market size passes a certain threshold, the rewards for increasing market shares grow much higher than the costs of investment and firms compete in demand-shifter spending prior to the final stage game, creating an additional entry barrier (besides the initial sunk cost investment) which, as Sutton (1998) proves, produces a constant minimum level of equilibrium concentration in the market regardless of its size (Figure 1).

Figure 1: Lower Bounds in the Presence of Endogenous Sunk Costs



1.4 Impact of an Increase in Competition Intensity on R&D Spending: Exogenous Case

The basic case of firms in industries where R&D expenditures do not play a large role as demand curve shifters (that is, in non-technologically intensive industries) is the following. The intensification of competition via trade creates two contradictory effects that operate simultaneously: (a) the market size effect, whereby firm access to larger markets and greater potential sales creates new incentives to innovate and increase R&D spending; [7] and (b) the competition effect, whereby an increase in competition intensity squeezes profit margins, making firms less able to engage in innovation and reduces R&D spending. The predicted outcome is ambiguous since for some industries the market size effect will far outweigh the competition effect (possibly due to easier commercialization or better differentiation for their product), while for others, the situation would be opposite.

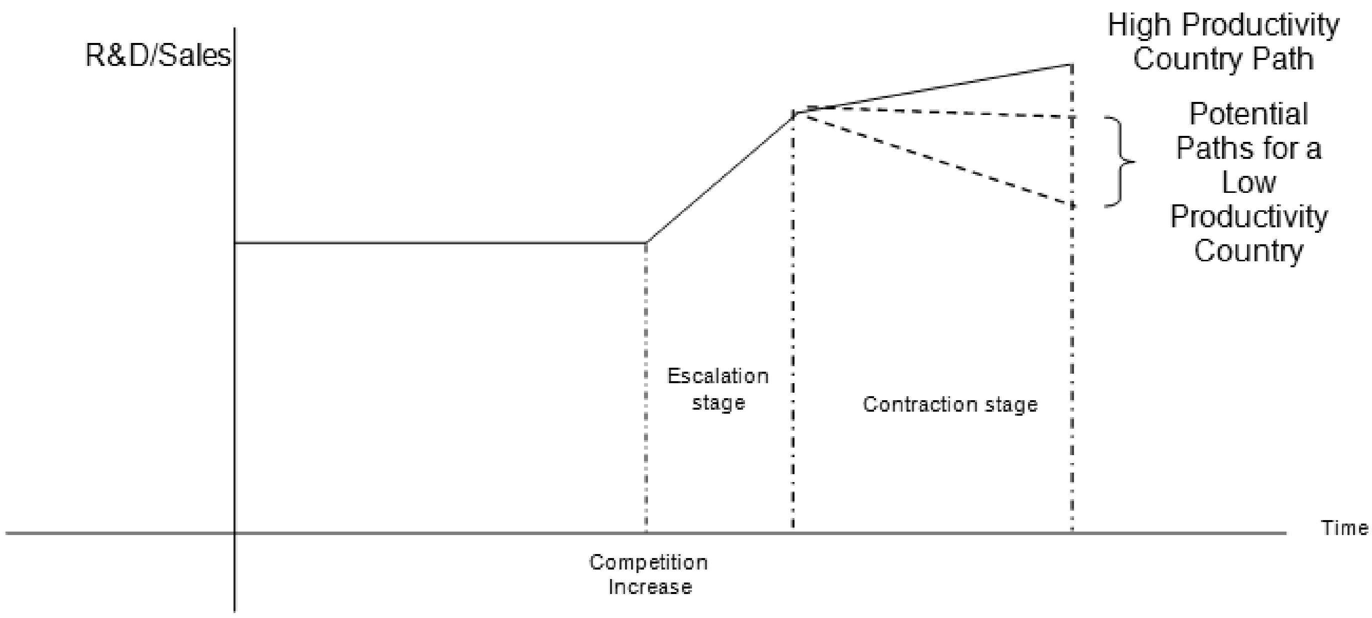
1.5 Impact of an Increase in Competition Intensity on R&D Spending: Endogenous Case

The market size and competition effects still apply in endogenous sunk cost industries, but there is also the added impact of R&D competition. Following an increase in trade, products become closer substitutes across countries, intensifying competition in the joint product market as firms in the industry now compete directly against both domestic and international rivals. As Sutton (1998) predicts, this also intensifies competition of spending on demand shifters as the incentives to gain increased shares of a much larger market are greater, and firms escalate R&D spending and increase the entry costs in the market.

Some firms are inevitably unable to maintain the escalation process for a long time (due to financial constraints, or to a lower efficiency of production), and proceed to reduce their R&D expenditures relative to their more efficient competitors. [8] On an international scale, if a majority of firms in a given industry in one country are better able to sustain the escalation due to some structural asymmetries such as higher productivity, the escalation and contraction process will be inherently unbalanced. Namely, firms in the more productive country, who continue to escalate their spending, would increase their R&D expenditures relative to firms in the less productive country. As a result, firms in the less productive country, which are unable to pay the sunk costs required to stay in the industry, would either drop out of the market entirely or move to producing goods that require less R&D and embody less value added. [9]

It should be noted that the contraction process does not necessarily leave firms in the less productive country with a lower innovation intensity compared to the start of the process; theory only predicts that the paths of high-productivity and low-productivity countries diverge following the contraction process, expanding the relative innovation gap between them (See Figure 2). Similarly, theory does not require the low-productivity country to initially have lower R&D intensity than the high productivity country; [10] the only assured outcome is that their paths diverge following the competition increase. Lastly, these theoretical predictions are based on the assumption that productivity differences between the countries are constant over the period examined – that is, it only takes into account the demand impact of R&D spending and innovation.

Figure 2: Escalation and Contraction Stages Following an Increase in Competition Intensity



2.1 Empirical Model

It is difficult to empirically measure sunk entry costs and model the equilibrium configuration of firms in the market. Bresnahan and Reiss (1991) do so for a number of professional industries, although they use hand-collected data and are forced to limit their investigation to small and isolated geographic markets. In Sutton (1991, 1998), empirics were done via illustrative individual case studies showing the impact of an external competition intensity shock on a given industry, either globally or locally.

The empirical analysis in this paper is modeled after Symeonidis (2002), the only known large scale econometric study using this theory. Symeonidis examines the impact of ending collusive practices in Britain in the 1950s on market structure and innovation. [11] In this study, we use the North American Free Trade Agreement between Canada and the US, a wholesale reduction in trade barriers in a large number of industries, as an external policy shock allowing us to measure the impact of a change in competition intensity on R&D spending intensity.

Using standard difference-in-difference methodology, we take the difference in R&D intensity between Canadian and US industries before and after NAFTA, as well as the total difference in R&D intensity over time to obtain a measure of the impact of NAFTA on R&D intensity in Canadian industries (the experimental group) relative to the US industries (the control group). We run two regressions – one for a group of R&D intensive industries and one for a group of non-R&D intensive industries [12] – since the characteristics governing R&D spending outcomes for endogenous and exogenous sunk cost industries are markedly different (see Sections 1.3 and 1.4 for more details).

The estimating equation (for industry *i*, at time *t*, and in country *c*) is, therefore:

$$\mathrm{RD}^{i}_{\mathrm{tc}} = \beta 0 + \beta 1\ \mathrm{InMES}^{i}_{\mathrm{tc}} + \beta 2\ \mathrm{CANADA}^{i}_{c} + \beta 3\ \mathrm{NAFTA}^{i}_{t} + \beta 4\ \mathrm{CANADA}{*}\mathrm{NAFTA}^{i}_{\mathrm{tc}} + \mathbf{D}^{i} + \partial^{i}\mathrm{tc}$$

Where $\mathrm{RD}^{i}_{\mathrm{tc}}$ is R&D intensity, [13] CANADA^{i}_{c} is a country dummy (which is 1 for Canadian industries), NAFTA^{i}_{t} is a dummy for whether the industry is in the period before or after NAFTA, [14] CANADA*$\mathrm{NAFTA}^{i}_{\mathrm{tc}}$ is the interaction term between the two, D^{i} is a vector of industry fixed effects, and ∂ is the residual term, which in particular may reflect measurement error across the sample. [15]

$\mathrm{InMES}^{i}_{\mathrm{tc}}$ is the logarithm of median firm sales divided by total sales in the market. This variable controls for the relative size of Canadian and US firms in a given industry. It is an important control, since there are heterogeneities in firm and market size which should play an important role in the R&D spending escalation and contraction process following NAFTA. [16]

β4 is the coefficient which measures the 'difference in differences' of R&D intensity for the experimental group of Canadian industries relative to their United States counterparts after the overall effects of NAFTA have been accounted for. As such, it is the variable of interest here. Since numerous studies show that Canadian industries lag their US counterparts in productivity and productivity growth, [17] we expect this coefficient to be negative for endogenous sunk cost industries.

2.2 Data Sources and the Sample of Industries

This study uses a sample of R&D intensive industries and a sample of non R&D intensive industries in Canada and the US to create two unbalanced panels covering the 1987-2002 period. By choosing this time-span, we are able to compare between the 1987–1994 and 1995–2002 sub-periods, which gives us ample sample space to estimate differences in R&D spending trends before and after NAFTA.

Following the selection process of Symeonidis (2002), seven industries with an R&D spending to sales ratio greater than 1% and with the highest number of observations for Canada and the US were selected as the endogenous sunk cost group for this study. [18] Seven other industries where R&D spending as a share of firms' sales rarely moved above the 1% threshold were selected to be the exogenous sunk cost group.

Industry Sample

R&D Intensive Industries		Non R&D Intensive Industries	
Industry	**NAICS**	**Industry**	**NAICS**
Fibers Manufacturing	3252	Textile Product Mills Manufacturing	314
Pharmaceutical Manufacturing	3254	Paper Manufacturing	322
Computer Equipment Manufacturing	3341	Petroleum and Coal Products Manufacturing	324
Communications Equipment Manufacturing	3342	Non-Metallic Mineral Manufacturing	327
Semiconductor and Other Electronic Components Manufacturing	3344	Iron and Steel Mills and Alloys Manufacturing	3311
Navigation, Measuring and Electromedical Instrument Manufacturing	3345	Alumina and Aluminum Production and Processing	3313
Aerospace Product and Parts Manufacturing	3364	Forging and Stamping Industry	3321

Due to data limitations, it was only possible to obtain complete data for R&D intensive industries at the 4 digit NAICS level for Canada and the US. Data was even more limited for the non-R&D intensive group, resulting in the use of a combination of 3 and 4 digit industries in the sample. This is a much higher aggregation than the one Sutton (1998) uses – a 5 digit SIC industry – although Symeonidis (2002) successfully uses similarly aggregated three and four digit SIC industries.

Three primary data sets are used for data on sales and R&D expenditures in industries: The annual *Research and Development in Canadian Industry* survey from Statistics Canada, the *Survey of Industrial Research and Development* from the National Science Foundation and the US Census Bureau, and the OECD's Structural Analysis STAN database. Additional data, such as the median firm size relative to total industry sales came from the Bureau of Economic Analysis in the US and from Statistics Canada. [19]

3.1 Descriptive Statistics

Summary Statistics (Canada and the United States)

	R&D Intensity		MES (Median Firm/Mkt Size)	
	R&D Intensive Industries	**Non-R&D Intensive Industries**	**R&D Intensive Industries**	**Non-R&D Intensive Industries**
Average 1987–1994	7.61	0.58	3.E−03	3.E−03
Std. Err. 1987–1994	4.06	0.39	1.E−02	1.E−02
Average 1995–2002	8.51	0.47	3.E−04	6.E−03
Std. Err. 1995–2002	5.38	0.24	7.E−03	1.E−03
Average 1987–2002	8.06	0.53	2.E−03	2.E−03
Std. Err. 1987–2002	4.78	0.33	7.E−02	7.E−02
N	223	218	224	224

Aggregate summary statistics suggest that R&D intensity has increased for R&D intensive industries between the two periods, thereby tentatively confirming the sunk cost theory predictions of an overall escalation in R&D spending after an increase in competition intensity. Conversely, for non-R&D intensive industries, R&D intensity declined between the two periods. As well, it appears that the MES for both R&D intensive and non-R&D intensive industries declined between the two periods, although this decline has been more pronounced for R&D intensive industries. However, not knowing more about the distribution of firm size, it is difficult to make conclusive remarks about the impact of NAFTA on the consolidation of firms in North America.

Summary Statistics

	Canada				United States			
	R&D Intensity		MES (Median Firm/Mkt Size)		R&D Intensity		MES (Median Firm/Mkt Size)	
	R&D Intensive Industries	Non-R&D Intensive Industries	R&D Intensive Industries	Non-R&D Intensive Industries	R&D Intensive Industries	Non-R&D Intensive Industries	R&D Intensive Industries	Non-R&D Intensive Industries
Average 1987–1994	8.00	0.47	6.E−03	6.E−03	7.23	0.68	8.E−05	6.E−04
Std. Err. 1987–1994	4.64	0.30	1.E−02	1.E−02	3.41	0.44	2.E−04	1.E−03
Average 1995–2002	8.52	0.39	6.E−04	1.E−03	8.51	0.55	5.E−05	2.E−04
Std. Err. 1995–2002	6.12	0.20	1.E−03	1.E−03	4.57	0.25	9.E−05	3.E−04
Average 1987–2002	8.26	0.43	3.E−03	3.E−03	7.87	0.61	7.E−05	4.E−04
Std. Err. 1987–2002	5.41	0.26	1.E−02	1.E−02	4.06	0.37	1.E−04	1.E−03
N	111	106	112	112	112	112	112	112

When separated by country, summary statistics show that Canadian industries' R&D intensity growth is 10% lower than their US counterparts, perhaps suggesting that less productive Canadian firms are unable to maintain the spending escalation at the United States rate. [20] It also appears that the MES in Canada is larger than that of the United States although this likely only reflects Canada's smaller market size.

An issue which comes out of the descriptive statistics is that Canada appears to have higher R&D intensity than the United States for the group of R&D intensive industries, which runs counter to the common perception (as confirmed by aggregate statistics) that Canadian firms have lower R&D intensity than United States firms. This may indicate problems with the data, or that a sample selection bias exists in the analysis. However, both of these are unlikely. Previous studies, such as ab Iorweth (2005), also find that Canada has a higher R&D intensity than the United States for multiple R&D intensive industries, but cannot explain this or find any evidence that these industries are markedly different than other similarly structured Canadian industries. Additionally, as stated before, sunk cost theory does not require that industries in low productivity countries should have lower R&D spending than industries in high-productivity countries. In fact, the absolute values are irrelevant, since the predictions center on relative trends.

3.2 Regression Results

Regression Results

$$\mathrm{RD}^i_{tc} = a\ \ln(\mathrm{MES})^i_{\mathrm{tc}} + b\ \mathrm{CANADA}^i_c + c\ \mathrm{NAFTA}^i_t + d\,\mathrm{CANADA} * \mathrm{NAFTA}^i_{\mathrm{tc}}$$

	R&D Intensive Industries	Non-R&D Intensive Industries
	Coeff (std. err.)	**Coeff (std. err.)**
ln(MES)	−1.60 ** (0.49)	−0.07 ** (0.02)
CANADA	8.21 ** (2.28)	0.04 (0.09)
NAFTA	1.79 * (0.73)	−0.07 (0.45)
CANADA*NAFTA	−3.94 ** (1.20)	−0.07 (0.07)
R^2	0.396	0.4698
N	223	218

Footnotes

* the coefficient is significant at the 90% confidence level.

** the coefficient is significant at the 95% confidence level.

Regression results largely confirm the theoretical predictions and observations from the descriptive statistics. For the regression of non-R&D intensive industries, the CANADA*NAFTA dummy is slightly negative and not statistically significant. As well, from the NAFTA dummy it seems that R&D intensity on the whole has fallen in both countries in the period following NAFTA. This is consistent with theory, since an escalation in R&D spending is not profitable in industries where it has a negligible impact on consumers' willingness to pay.

The dummy representing the overall change over time is positive and highly statistically significant for R&D intensive industries, showing that when focusing on all industries in both countries, R&D intensity increased on average in the period after NAFTA. This is consistent with the theoretical predictions of escalation. Observing the Canada-US differences across industries, the dummy representing the change of Canadian industries relative to US industries over time (CANADA*NAFTA) is negative, and statistically significant at the 1% confidence level. In fact, taking the total derivative of R&D intensity with respect to NAFTA shows that Canadian industries experienced an average net loss of 1.1% in R&D intensity, while US firms experienced an average net gain of 1.8%. Consistently with theory, it appears that despite an absolute increase in R&D investment, Canadian R&D intensive industries lost some ground compared to similar US industries in the period after NAFTA.

4. Conclusions

Using Canadian and US industry level data for 1987–2002, the findings of this paper provide some systematic empirical evidence on the impact of an increase in competition intensity via globalization on innovation intensity in countries with heterogeneous productivity levels (holding relative productivity levels constant). The evidence is consistent with the theoretical model of endogenous sunk costs and suggests that an exogenous increase in competition in the post NAFTA period produced an *absolute increase* in R&D investment in R&D intensive industries in Canada and the US. However, the less productive Canadian industries *fell relative to their US counterparts* in R&D intensity levels.

These results potentially suggest some answers to the generally accepted but unexplained stylized fact, that despite Canada's extensive R&D support programs [21], the R&D intensity gap between Canada and the United States has persisted over the last twenty years. These results are also consistent with recent studies which find Canadian firms to be less innovative in their strategic outlook compared to their US counterparts.

Of course, it should be noted that this study is a simple difference-in-difference comparison between two periods; as such, it does not present evidence of a definitive causal link between NAFTA and innovation investment patterns, but merely a suggestion regarding the form such a link might take. In addition, the economic impact of trade on firms varies depending on factors such as their products, location, and size (Melitz 2003). This study uses industry level data, and as such it fails to incorporate firm heterogeneity into the analysis – particularly important since evidence suggests that large firms (500+ employees) explain much of the R&D investment gap between Canada and the US (Songsakul, Lau, and Boothby 2008). Future research should use firm level data in examining changes in the dynamic investment process of firms following an increase in competition intensity. Sutton's theory suggests that firms which lag in R&D investment in R&D intensive markets are forced to either exit the markets entirely, or to focus on producing lower value added goods which require less technological inputs. It is unclear whether this occurred in the period following NAFTA, and it could be examined further using appropriate data.

This paper also assumes that productivity differences between the two countries are constant over the period examined – it does not take into account the supply side impact of investment in innovation. Expanding the study to incorporate the possibility that investing in innovation does not only expand demand but also improves efficiency could produce further insights into the interaction between innovation, competition and market structure following globalization.

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Footnotes

1 As detailed in Symeonidis (1997), and Kamien and Schwartz (1982), among others.

2 e.g. Aghion, Harris and Vickers (1997) and Aghion, Harris, Howitt and Vickers (2001).

3 Such as Scherer (1967), Kamien and Schwartz (1982) and Aghion et al (2005).

4 Among other failures, in much of the literature, a greater degree of market power is often equated with a higher level of concentration, which has been proven to be both theoretically and empirically incorrect. For more details, see Demsetz (1973) and Boone (2000).

5 The model can be applied to a variety of market structures, and it has been explored in depth in other papers dealing with oligopoly games and entry and exit - such as Bresnahan and Reiss (1991).

6 This assertion draws on Shaked and Sutton (1987), which states that in an industry where consumers are willing to spend more on products of higher quality, a high quality incumbent cannot be pushed out of the market by a low quality entrant, regardless of how the low-quality product is priced.

7 See, among others, Girliches (1957), and more recently Acemoglu and Linn (2004).

8 This process is described in Sutton (1991) for the frozen foods industry. Following deregulation, producers of frozen foods separated into two groups – large producers who invested heavily in advertising and sold their products on the commercial market (i.e. in supermarkets), and small producers who did not invest in advertising at all and sold their products to bulk suppliers. As well, a similar process is described in Melitz (2003), as high productivity firms take on a majority of an industry's trade following an exogenous increase in competition intensity.

9 The chain of events described here becomes more complicated if the investment in innovation does not only push demand outward, but also reduce the costs of production. This analysis is beyond the scope of the current paper.

10 In fact, it could have higher R&D spending due to various factors such as mandated government rules.

11 Specifically, Symeonidis' empirical model regressed the number of patents produced by the industry (a measure of R&D output) on the logarithm of market size, the logarithm of set-up costs of a firm in a given industry, and time dummies that represent the changes in competition policy between different periods.

12 Note: according to theory, firms invest in R&D only if it is profitable. As a result, industries with high R&D intensity ratios are assumed to have the characteristics of endogenous sunk cost industries, and the two terms are used interchangeably in this paper.

13 Defined, for a given industry, as the total R&D spending of R&D producing firms, divided by the total sales of these firms, multiplied by 100%.

14 We take 1994-5 as the breakpoint, since although NAFTA was signed in 1992, its consequences were not truly felt until the mid 1990s.

15 Additional controls such as bilateral tariff rates for the two groups of industries were experimented with, but did not add explanatory value to the endogenous sunk cost regression and did not change the main results of the exogenous sunk cost regression.

16 A similar issue is discussed in Sutton (1998) when examining the impact of a loosening of international trade barriers on the electronic telecommunications equipment industry. Specifically, the French telecommunications firm Alcatel, which enjoyed a near monopoly of the French market, succeeded in surviving the escalation in R&D spending and expand internationally. In other countries where market shares were small, the firms could not maintain the escalation process, and they either left the industry, or they were taken over by larger foreign firms.

17 See Rao and Sharpe (2002), Rao, Tang and Wang (2004), or Chen (2006) for recent Canada-US productivity comparisons.

18 In addition to this rationale, most of the selected industries were used in previous sunk costs studies. For example, Sutton (1998) uses the aerospace parts manufacturing industry as one of the major endogenous sunk cost cases, and Symeonidis (2002) includes all of the industries in the sample under the endogenous sunk cost category as well. While this may introduce some sample selection bias and tautology into the results, testing the effect of changes in competition on R&D spending according to Sutton's theory does require specific industry characteristics to be apparent, which this classification accomplishes.

19 Due to data limitations, it has only been possible to include the 1997 and 2002 values for this variable. Other values have been interpolated using the market size annual growth rates, under the restricting assumption that the median sized firm also grew proportionally.

20 Note that the growth of R&D intensity in both countries is not a statistical artifact driven by the sales with actual R&D spending held constant. For both Canadian and US industries, R&D expenditure is the main driver of changes in R&D intensity.

21 Canadian R&D support programs include venture capital support for entrepreneurs, tax incentives for R&D performance by firms, as well as some explicit regulations forcing firms to invest a certain percentage of their profits in research and development in the Pharmaceutical industry. These programs receive generous funding, as evidenced by OECD (2006) ranking Canada's government tax incentives for innovation as highest of all G7 countries.