Economics Bulletin

Volume 32, Issue 1

Non-Collusive Oligopoly and Business Cycle: Some Further Evidence

Marcelo Resende
Instituto de Economia, Universidade Federal do Rio de Janeiro

Abstract

The paper examines the differential exercise of market power over the business cycle in the context of selected sectors in the Canadian manufacturing industry during the 1992-1/2007-4 period. In particular, empirical implications of non-collusive models previously explored by Wilson and Reynolds (2005) are further investigated by considering data for selected disaggregated and homogeneous sectors and is consistent with a multiple regimes formulation. A main implication concerning differential variances for changes in prices in the two demand regimes is partially supported in the investigated sectors.

The author acknowledges research assistance from João Marcos Tavares and financial support from CNPq and yet comments from an anonymous referee but the usual caveats apply.

Citation: Marcelo Resende, (2012) "Non-Collusive Oligopoly and Business Cycle: Some Further Evidence", *Economics Bulletin*, Vol. 32 No. 1 pp. 883-893.

Contact: Marcelo Resende - mresende@ie.ufrj.br.

Submitted: February 06, 2012. **Published:** March 15, 2012.

1. Introduction

Tacit collusion is an elusive phenomenon and not surprisingly, explicit cartels like the Joint Executive Committee have provided a fruitful ground for empirical studies that assessed the prevalence of multiple pricing regimes in oligopolies [see e.g. Porter (1983), Berry and Briggs (1988) and Ellison (1994)].

The potential occurrence of differential market power over the business cycle was further clarified by the literature relying on game-theoretic collusion models. In fact, the influential papers by Green and Porter (1984) and Rotemberg and Saloner (1986) highlight the existence of trade-offs between short-run gains from deviating from the cartel and the long-run expected punishment costs that can depend on the business cycle. Bagwell and Staiger (1997) further enriched the analysis by allowing for demand shocks that might be persistent. The predictions of the different models reflect distinct assumptions with regard to punishment strategies, the nature of demand shocks and the observability of the variables [see e.g. Slade (1990)]. The bulk of the related literature focuses on supergames and rely on strong forms of collusion. In contrast, Wilson and Reynolds-WR (2005) emphasize the role of long-run production capacity investments in shaping the market power over the business cycle. That dynamic model is referred as non-collusive in contrast with the aforementioned optimal collusion models that considered more sophisticated settings.

The initial empirical evidence on non-collusive oligopoly provided by WR is broadly consistent with the main implications accruing from the underlying theoretical model that would indicate differential distributional patterns for price changes across expansion and recession regimes for demand.

The present paper intends to provide additional evidence on the implications of non-collusive models of oligopoly by considering more detailed data in the context of the Canadian manufacturing industry. Those implications relate to distinctive patterns for variance of price changes and distributional patterns that depend on the unobserved state of the business cycle. In particular, one intends to contribute in terms of the following aspects:

a) The consideration of more disaggregated sectoral data and the selection of more homogeneous sectors. This last aspect is particularly important as the underlying theoretical model does not assume product differentiation;
b) The consideration of data that more readily portray movements in demand by focusing on sectoral sales data instead of production;

The paper is organized as follows. The second section discusses conceptual aspects related to non-collusive oligopoly and outlines the econometric framework to be considered. The third section discusses the data construction and presents the empirical results from the econometric estimation. The fourth section brings some final comments.

2. Non-Collusive Oligopolies: a Digression

2.1- <u>Conceptual Aspects</u>

The differential exercise of market power over the business cycle has been studied in terms of optimal collusion models with infinitely repeated games. Influential papers include Green and Porter (1984) and Rotemberg and Saloner (1986) that legitimated price wars as an equilibrium phenomenon and respectively led to procyclical and countercyclical predictions. The results largely depend on the assumptions regarding the degree of observability of demand shocks [see Tirole (1988) for pedagogical presentations of the referred models]. The empirical evidence, however, is not clear cut. An influential study was provided by Domowitz et al. (1987) that constructed annual price cost margins at the 4-digits SIC for industries in the U.S. during the 1958-1981 period. Care was taken to select more homogeneous industries for which a clearer relationship between margins and the Lerner index can be motivated. The most salient result arising from a panel estimation provided some evidence on countercyclical pattern for margins if one takes capacity utilisation as the business cycle proxy. However, a potential shortcoming of their approach relates to biases associated with discrepancies between marginal and average costs as the maintained hypothesis for the construction of the sectoral profit margins was their equality. Machin and van Reenen (1993) and Lima and Resende (2004) undertake a more detailed research strategy by focusing on firm-level panel data for the U,K, and Brazil cases respectively. The studies provided support for a procyclical behaviour of profit margins

It is important, however, to consider more direct implications of collusive models, but optimal collusion attributes sophisticated behaviours for the agents that do not exhaust the possibilities of exercise of market power over the business cycle.

Wilson and Reynolds-WR (2005) empirically address the possibility of differential exercise of the market power but without focusing on optimal collusion. They consider a dynamic model of capacity investment and pricing. A sequence of investment and price decision are taken by firms over an infinite horizon. Furthermore, each period is divided in two stages: first firms simultaneously invest in production capacity and second simultaneously choose prices after having observed the choices of the previous stage. A central aspect of the model pertains demand uncertainty that complicates irreversible investment decisions. In that aspect, the authors adopt a Markovian specification for demand growth that resembles the one considered by Bagwell and Staiger (1997). Those authors generalized Rotemberg and Saloner (1986) by allowing persistent demand shocks. That probabilistic specification for demand growth will provide the essential motivation for an empirical analysis based on Markov-switching models that is implemented in the next section. However, the non-collusive model advanced by WR does not require sophisticated optimal collusion mechanisms. The most salient results that emerge refer to general features of the subgame perfect equilibrium of the model. In the short-run competitive price is a pure Strategy Nash equilibrium in the case of an expansionary demand regime. In a recessionary regime, however, prices are set above the competitive level and therefore one can predict a countercyclical pattern with respect to market power. Additionally, more complex behaviours emerge in the recessionary regimes as firms would employ mixed pricing strategies and favour greater variability in prices under that demand regime. Two empirical implications can be explored:

(a) During the recessionary regime ($s_t = 2$) changes in price will exhibit a larger variance;
(b) Distinct distributions for changes prices prevail in the two regimes. For example, in a normality setting, mixed strategies in the recessionary regime would imply a non-normal component that does not prevail in the expansion regime

In the next section, I implement an empirical analysis that first consider the general adequacy of the bivariate Markov-switching model and then focuses on the aforementioned empirical implications.

2.2- Econometric Framework

Markov-switching models provide an appealing framework for empirically assessing multiple pricing regimes. The empirical implications of the model discussed in the previous section will be tested in terms of a bivariate Markov-switching model without autoregressive dynamics along the lines of Engel and Hamilton (1990) and Hamilton (1990). [1]

The multivariate extension of more usual univariate Markov-switching model can be summarized as follows:

$$\mathbf{y_t}|s_t \sim N(\mu_{s_t}, \Omega_{s_t}) \qquad (1)$$

This expression specifies a normal conditional distribution with that depends on the unobserved state (regime) s_t in period t and accommodates the possibility of distinct means and variances in the expansion and recession regimes. In the particular application considered in this paper, one has $\mathbf{y_t} = [q_t,p_t]'$ where the elements respectively refer to quantity and price changes. Thus, μ_1^q and μ_2^q respectively denote the mean for quantity changes in regimes 1 and 2 whereas μ_1^p and μ_2^p indicate related definitions for price changes in the two regimes. Analogous concepts for the variance of a given change in price or quantity under the two regimes are indicated by σ with the aforementioned subscripts and subscripts. As previously mentioned, the model emphasizes unobservable regimes (states) for demand that can expansionary or recessionary.

Maximum likelihood estimates for that model can be obtained by the EM algorithm [see e.g. Dempster et al. (1977)]. In order to assess the empirical evidence on the adequacy of non-collusive models of oligopoly, the following steps will be necessary:

(i) Estimation of a bivariate Markov-switching model for changes in quantities and prices;

(ii) Consideration of specification tests to verify if clearly distinct regimes appear to prevail in the selected sectors. Specifically, a Wald test on the equality of means across regimes for one of the component series of $\mathbf{y_t}$ can be conducted with the following test statistic [see Hamilton (1996)]:

$$\frac{(\hat{\mu}_1 - \hat{\mu}_2)^2}{Var(\hat{\mu}_1) + Var(\hat{\mu}_2) - 2\,C\hat{o}v(\hat{\mu}_1, \hat{\mu}_2)} \qquad (2)$$

That will be asymptotically distributed as a $\chi^2(1)$ under the null hypothesis of equal means across regimes

The first two items provide an initial evaluation of the adequacy of the Markov-switching model whereas the next two items refer to more specific empirical implications following from the work by WR.

(iii) Test of the equality of variances for changes in price across regimes that can be accomplished by means of a likelihood ratio test. The usual test is implemented by comparing the maximum likelihood value of the unrestricted model with the value accruing upon the imposition of a restriction where the variances of price changes are assumed to be equal across states;

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[1] General overviews of Markov-switching models can be found in Hamilton (1993,1994) and Kim and Nelson (1999).

(iii) Differential distributions across regimes are assessed in terms of normality tests. Non-normalities could arise in the recessionary regime in connection with mixed strategies. First, the regimes can de dated by considering the smoothed probabilities. The regime 2 (recessionary regime) can be identified by considering observations where $p(s_t=2|\mathbf{y_1},\ldots,\mathbf{y_T};\ \hat{\theta}) > 0.5$, where $\hat{\theta}$ stands for the parameter vector. Second, traditional Kolmogorov-Smirnov-KS tests are carried out for price changes in the two regimes sub-samples [see Siegel (1956) for an overview]. Finally, more detailed tests aim at verifying the consistency of skewness and kurtosis with a normal distribution by considering tests presented in Cromwell et al (1994). The skewness and kurtosis coefficients respectively represent the third and fourth order moments for a standardized variable . Let $z_i = (X_i - \overline{X})/s_X$ denote a generic standardized variable, the referred coefficients a era respectively defined as:

$$\frac{1}{T}\sum_t z_t^3 \equiv (\beta_1)^{1/2} \qquad \text{e} \qquad \frac{1}{T}\sum_t z_t^4 \equiv \beta_2 \tag{3}$$

To verify departures from normality associated with skewness $(\beta_1)^{1/2}$ can be considered as normally distributed with zero mean and standard deviation $(6/T)^{1/2}$ and thus the test statistic v_1 allows to evaluate the null hypothesis of normality against an alternative involving an asymmetric distribution. Specifically:

$$V_1 = (\beta_1)^{1/2}/(6/T)^{1/2} \tag{4}$$

Such test statistic can be evaluated in terms of a standard normal distribution under the null hypothesis. In order to capture departures from normality related to the kurtosis, one has β_2 that would be normally distributed with mean zero and standard deviation $(24/T)^{1/2}$. The null hypothesis of normality would be associated with a kurtosis coefficient equal to 3, and leads to the following test statistic:

$$V_2 = (\beta_2 - 3)/(24/T)^{1/2} \tag{5}$$

Once more, an asymptotically normal distribution arises under the null hypothesis. The next section implements the empirical analyses just outlined.

3. Empirical Analysis

3.1- Data Construction

The paper considers data for the Canadian manufacturing industry available at *Statistics Canada* (www.statcan.gc.ca). Specifically, monthly data in terms of the North America Industrial Classification System-NAICS (in accordance with the 2002 criteria) were gathered for producer price indexes and sales along the period 1992-1/2007-4. As previously mentioned it is important to consider disaggregated and homogeneous sectors in the analysis and I´m not aware of other country with adequate price and quantities data. Moreover, a longer series was not possible as the data availability started on the specified initial month in the early 90s. In that sense, a selection of 50 sectors was initially considered for the estimation of the bivariate Markov-switching model. However, for the majority of those (46 sectors) the referred model was not successful and led to insignificant coefficients for the regimes´ variables and therefore the analysis focused on 4 sectors (asphalt paving, glass, cement and metal tank manufacturing). The bivariate model for changes in quantities and prices was based on the difference of the natural logs of the variable in levels multiplied by 100. The variables in levels were initially deflated by the producer price index for the whole manufacturing industries.

3.2- *Empirical Results*

In this section, one tests empirical implications related to the work by Wilson and Reynolds-WR (2005). The econometric estimations for bivariate the Markov-switching model were carried out with Gauss 8.0 by marginally adapting the code EMEST.NEW developed by James Hamilton. In particular, Engel and Hamilton (1990), unlike most of the applications of Markov Switching models, consider Bayesian priors to improve the precision of the estimates. In the absence of more definite prior beliefs on the parameters, it was preferred not to impose those. In fact, the authors clearly suggest that it is possible to disregard Baysesian priors by setting specific terns in the log-likelihood equal to zero and can be readily implemented in the Gauss code developed by the first author.[2]

The estimates for the bivariate model are reported in table 1.

The statistical fit of the models was in general adequate in terms of the significance of individual coefficients. Nevertheless, one observes in the cases of glass and metal tank manufacturing non-significant coefficients for the price mean in one regime. Moreover, coefficients display heterogeneous patterns across the different sectors.

However, in contrast with WR, one does not observe uniformly persistent regimes. In fact, there had been evidence on that feature in the context of exchange rates and mergers [see e.g. Engel and Hamilton (1990) and Resende (1999) respectively]. In the present case, clear evidence on persistence under both regimes only prevails in the case of asphalt paving whereas in other cases one also observes persistence in only one of the regimes and moderate magnitudes in the staying probabilities otherwise.

[2] See the remark by Engel and Hamilton (1990, pp. 694)

Table 1
Estimates for the bivariate Markov-switching model for $\mathbf{y_t} = [q_t,p_t]'$

	Sector							
	Asphalt paving		Glass		Cement		Metal tank	
μ_1^q	12.871 (1.899)		5.246 (0.885)		10.338 (1.423)		2.756 (1.184)	
μ_1^p	0.893 (0.176)		-0.039 (0.068)		-0.107 (0.073)		1.459 (0.580)	
μ_2^q	-29.794 (5.649)		-12.126 (3.190)		-33.874 (3.735)		0.232 (1.143)	
μ_2^p	-1.477 (0.336)		-0.432 (0.243)		0.412 (0.200)		-0.102 (0.049)	
p_{11}	0.876 (0.033)		0.634 (0.082)		0.892 (0.027)		0.493 (0.176)	
p_{22}	0.687 (0.079)		0.112 (0.102)		0.616 (0.085)		0.939 (0.025)	
Ω_1	311.751 (42.076)	1.836 (2.841)	65.431 (10.754)	-0.365 (0.539)	225.809 (29.371)	0.459 (1.099)	9.673 (4.958)	-1.315 (1.790)
	1.836 (2.841)	2.975 (0.398)	-0.365 (0.539)	0.446 (0.086)	0.459 (1.099)	0.605 (0.091)	-1.315 (1.790)	2.868 (0.963)
Ω_2	518.090 (137.360)	6.411 (7.333)	203.704 (46.520)	-4.014 (3.674)	176.888 (82.072)	-1.668 (3.318)	255.447 (29.289)	0.406 (0.743)
	6.411 (7.333)	3.005 (0.673)	-4.014 (3.674)	2.394 (0.523)	-1.668 (3.318)	1.351 (0.311)	0.406 (0.743)	0.371 (0.044)

Note: standard errors are in parentheses and the complete description of the sectors are provided in table 2

Next, the adequacy of the aforementioned Markov-switching models is further assessed by considering tests for difference of means across regimes, These Wald tests allow to check for discernible differences in regimes for changes in quantities and prices. The results are summarized below.

Table 2
Tests for Difference of Means Across Regimes

Industry	H_0: $\mu_1^q = \mu_2^q$ H_1: $\mu_1^q \neq \mu_2^q$ Test Statistic	H_0: $\mu_1^p = \mu_2^p$ H_1: $\mu_1^p \neq \mu_2^p$ Test Statistic
Asphalt paving, roofing and saturated materials manufacturing	67.075 (0.000)	45.391 (0.000)
Glass and glass product manufacturing	30.216 (0.000)	2.176 (0.140)
Cement manufacturing	157.131 (0.000)	5.388 (0.020)
Metal tank (heavy gauge) manufacturing	1.998 (0.158)	7.150 (0.008)

Note: p-values are reported in parentheses

The evidence partially indicates that one can identify 2 markedly distinct regimes in all the four sectors considered. However, exceptions occur in the cases of the quantity regimes for metal tank manufacturing and yet price regimes for glass manufacturing.

Therefore, tables 1 and 2 provide preliminary evidence on the adequacy of the bivariate Markov-switching, while the next tables address the empirical implications of the model by WR. A first salient implication pertains the difference in variances in price regimes. The results are reported next in table 3. At first, one notices apparent significant differences in the case of glass and cement when one considers the ratio of variances and a counterintuitive result for metal tank manufacturing.

The evidence from likelihood ratio tests is favourable and convincing in 2 sectors (glass and cement manufacturing) whereas it was inconclusive in the case of metal tank manufacturing.

Finally, the distributions of changes in prices in the two regimes are examined by means of normality tests presented in table 4. Unlike the predictions from the non-collusive model that suggested differential distributional patterns across the demand regimes, one observes somewhat similar distributional characteristics. That is the case whether a general normality tests like the KS is considered or tests focusing on the third and fourth moments of the distributions are implemented. Moreover, the evidence does not favour non-normalities that could arise in the recessionary regime due to mixed strategies. It is important to note that the KS constitutes a general test for normality whereas V_1 and V_2 aim at assessing normality violations that are respectively related to distortions in skewness and kurtosis. The rarity of price wars intuitively would favour asymmetric distributions for price changes. As for violations related to kurtosis one would be dealing with relatively flat distributions and relatively low probabilities for moderate price changes. Thus, one needs not to fully expect a complete agreement of the "partial" tests. Nevertheless, in the case of metal tank sector the overall evidence shows discrepancies relative with those partial tests.

Table 3
Test of different variances across regimes

Industry	H_0: $\sigma^2_{1p} = \sigma^2_{2p}$ H_1: $\sigma^2_{1p} \neq \sigma^2_{2p}$ likelihood ratio test	p-value	$\frac{\sigma^2_{2p}}{\sigma^2_{1p}}$
Asphalt paving	0.006	0.938	1.01
Glass	17.202	0.000	5.37
Cement	29.524	0.000	2.23
Metal tank	n.a.	n.a.	0.13

Note: n.a.: not available as the EM algorithm did not converge under the restricted model with equal variances for changes in prices

Table 4
Normality tests for changes in prices

	Expansionary regime			**Recessionary regime**		
	KS	V_1	V_2	KS	V_1	V_2
Asphalt paving	1.046 (0.224)	1.165E-16 (1.000)	-6.150 (0.000)	0.668 (0.728)	0.034 (0.973)	-5.399 (0.000)
Glass	0.987 (0.284)	2.600 (0.009)	0.708 (0.479)	0.858 (0.418)	8.649 (0.000)	0.480 (0.631)
Cement	0.689 (0.730)	0.984 (0.325)	1.830 (0.067)	0.550 (0.897)	0.520 (0.603)	0.968 (0.333)
Metal tank	0.479 (0.961)	-10.480 (0.000)	10.510 (0.000)	0.825 (0.504)	1.701 (0.089)	0.958 (0.338)

Note: p-values are reported in parentheses

4. Final Comments

The paper aimed at testing implications of the model for non-collusive oligopoly advanced by Wilson and Reynolds (2005). The evidence indicated that a bivariate Markov-switching model for quantities and price changes does not exhibit an adequate fit in a large proportion of more disaggregated and homogenous sectors in the case of Canadian manufacturing industry. For the remaining selected sectors discernible distinct regimes appear to prevail in many cases. As for the specific implications of the model of non-collusive oligopoly by RW only partial support prevails in terms of differential variances for changes in prices across demand regimes. The robustness analysis considered in this paper can be motivated by a need of a closer matching with the underlying theoretical model , In fact, the use of Canadian data allowed to consider more homogeneous and disaggregated sectors and more demand-related data for quantities. Altogether those aspects may bypass some potential shortcomings that can prevail in American data.

The evidence is not unambiguously consistent with implications from non-collusive models of oligopoly. One, however, should not expect that a particular model for differential market power over the business cycle should be supported in many different sectors as the sector-specific characteristics pertaining the nature of demand shocks, observability of variables and nature of punishment are likely to play an important role in that relationship. Therefore, an important avenue for future research would contemplate tests of empirical implications of other models that address the issue of differential market power over the business cycle (including collusive models) with sectoral data. Despite the limitation of temporal aggregation associated with the available monthly data that line of research could be useful so that in a later stage one can obtain a better understanding of sectoral characteristics that appear to be decisive in the prevalence of particular forms of exercise of market power.

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