Inflation and Economic Growth with Cross-Section Dependency: an Empirical Analysis in Terms of Relative Price Variability across Canadian Provinces

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Abstract

This paper empirically provides new evidence on the relation between inflation, relative price variability and economic performance or living standards to a panel of Canadian provinces over the period 1981-2010. We use the Bick and Nautz (2008) modified version of Hansen's (1999) Panel Threshold Model. The evidence strongly supports the view that the relationship between inflation and economic growth is nonlinear. Further investigation suggests that relative price variability is one of the important channels through which inflation affects economic performance in Canadian provinces. When we control cross-section dependency and use the appropriate method, we find the critical threshold value slightly changes. Our findings are consistent with the claims of Blanchard et al. (2010) who suggest that an inflation target of 4 percent might be more appropriate because it leaves more room for expansionary monetary policy in the case of adverse shocks. These findings provide some policy implications. It is desirable to keep inflation in the moderate inflation regime and therefore the Bank of Canada should concentrate on those policies which keep the inflation rate between 1.82 percent and 4.16 percent because it may be helpful for the achievement of sustainable economic growth and to improve the living standards of Canadian provinces. The results seem to indicate that inflation that is too high or too low may have detrimental effects on economic growth. This information gives a very important signal for Canadian policymakers to impose new policies to provide economic stabilization through Canadian provinces.

JEL Codes: E31; E3; E51; E23; C21; C23; C33;

Keywords: Inflation; Relative price variability; Growth; Generalized Least Squares; Threshold effects; Cross-Section dependency; Seemingly Unrelated Regression Equations

1 Introduction and Motivation

One of the objectives of macroeconomic policies is to achieve high and sustainable economic growth rates along with low, stable and predictable inflation rates. For that reason, the relationship between economic growth and inflation is fundamental for policymakers. If these two variables are interrelated, then policymakers would like to control them depending on the structure of such relationship in order to each policy targets. Considering its importance, the inflation-growth relationship has attracted much attention from economists, both in academia and in the world of central banking. Several theoretical and empirical studies explored this issue and reached several conclusions. Indeed, if one agrees that the origins of inflation are triple (money, cost and demand), the channels through which it affects economic growth are subject to controversy. There are three possible results regarding the impact of inflation on economic activity: i) none; ii) positive; and iii) negative. Sidrauski (1967) established the first result, showing that money is neutral and superneutral[1] in an optimal control framework, claiming that an increase in the inflation rate does not affect economic growth. Tobin (1965), who assumed money is as substitute to capital, established the positive impact of inflation on growth; his result is being known as the Tobin effect. The negative impact of inflation on growth is associated mainly with cash-in-advance models (e.g., Stockman, 1981) which consider money as complementary to capital. Clearly, inflation could have different impacts on economic growth. Indeed, inflation imposes negative externalities on the economy when it interferes with an economy's efficiency. Inflation can lead to uncertainty about the future profitability of investment projects. This leads to more conservative investment strategies than would otherwise be the case.

Higher inflation may also reduce a country's international competitiveness, by making its exports relatively more expensive, thus impacting on the balance of payments. Moreover, inflation can interact with the tax system to distort borrowing and lending decisions.

[1]Money is neutral when an increase in money supply leads to an equal increase in all prices and no real variables are affected. Money is superneutral when changes in the growth rate of money supply have no effect on the real variables of the economy (Romer, 1996). This role of money is very close to the one described by the quantity theory of money in the long run (see Lucas, 1996).

As important as the possible relation between inflation and growth may be Ragan's (2000) review of the research shows the difficulty in finding clear and convincing evidence that a linkage exists. Following Blanchard et al. (2010), the effects of inflation on growth are difficult to discern, so long as inflation remains in the single digits. As a consequence, they suggest that an inflation target of 4 percent might be more appropriate because it leaves more room for expansionary monetary policy in case of adverse shocks. What is clear is that, in the countries that have experienced very high inflation, there is a significant and negative effect on economic growth.[2] What is much less clear from the empirical research is whether there exists any relationship between economic growth and inflation in countries that already have low or even moderate, inflation. According to Ragan (2005), in a country with an inflation rate of, say, 5 percent per year, it is not clear from the data that a policy decision to reduce inflation would have any positive impact on long-run economic growth. We assume that this result depends on particular assumptions about the shape of the estimated model (linear or nonlinear model) or of the policy variable considered in the model (inflation target or relative price variability) or the nature of the data used. Therefore, following the earlier literature and recent studies at the Bank of Canada which suggest that price level targeting is a welfare-improving policy relative to inflation targeting, besides looking at the relation between inflation and economic growth, we investigate the relationship between relative price variability and economic growth. We also assume a nonlinear model specification.

This has given a renewed interest in the debate on relative price variability. Variability in relative prices is known to be a major channel through which inflation can induce welfare costs by impeding an efficient allocation of resources in the economy. As Friedman (1977) made clear in his Nobel lecture, relative price variability is a direct means by which inflation can induce welfare-diminishing resource misallocation. Since the influential paper by Parks (1978), several studies, using Parks's (1978) framework, have provided evidence in favour of a significant impact of inflation on relative price variability.[3] Consequently, substantial effort has been devoted to the examination of the link between relative price variability (RPV) and aggregate inflation.

[2]When inflation becomes very high; money is losing its value so quickly that it soon ceases to be useful as either a medium of exchange or as a store of value.

[3]See Parsley (1996), Bick and Nautz (2008), Fernandez Valdovinos and Gerling (2011) and Tanimoune and Fiodendji (2011).

Although much of the existing theoretical and empirical literature points to a positive monotonic relationship, newer contributions suggest that the relationship between inflation and RPV is more complicated, particularly in terms of its sensitivity to the inflation regime. In Canada, the dual problem of the relationship between inflation and growth and between inflation and relative price variability has given rise to few empirical investigations. Monetary authorities have an ongoing interest in the relationship between inflation and economic growth through relative price variability in Canada. Binette and Martel (2005) investigate empirically the relationship between different aspects of inflation and relative price dispersion in Canada using a Markov regime-switching Phillips curve. They observe a strong asymmetry regarding the impact of positive and negative unexpected inflation on relative price dispersion using total inflation, but this asymmetry is not observed for core inflation. This suggests that the strong asymmetry arises mainly from the presence of components typically associated with supply shocks, and not from the presence of downward nominal rigidities. Omay and Kan (2010) analyze the empirical relationship between inflation and output growth using a panel smooth transition regression model for six industrialized countries including Canada. Their model takes into account the control of cross-section dependency and unobserved heterogeneity at both country and time levels. They find a stronger negative relationship between inflation and growth for inflation rates above a critical threshold level (2.5%).

Our paper aims to improve our understanding of this relationship. Our work differs from the recent literature in the following way: Rather than asking how well inflation or relative price variability affects economic growth for various countries, as has been done in previous empirical research on this topic, we ask how this relationship olds across Canadian provinces. On the one hand, it is not expected that the analysis would hold at the provincial level since provinces respond to the same monetary policy and have the same central bank. It is possible that different provinces are hit by different shocks and therefore relative prices have to adjust. Another possibility is that provinces react differently to common shocks. The Bank of Canada is committed to aggregate inflation and has one instrument for this purpose. Even if there are deviations from the target in some provinces, the Bank cannot react to all of them, due to the limitations of the one instrument-one target link, as long as overall inflation is not affected. By analyzing provincial data, we take a look at possible asymmetries in the economic structure of provinces. We are not the first to analyze provincial disparities in Canada (Chaban and Voss, 2010). What is novel in our approach is to use the dynamics panel data with cross-section dependence to improve the design of monetary policy in Canada.

If the inflation-targeting framework in Canada is believed to increase the credibility of monetary policy, to enhance the anchoring of expectations of future inflation, and to reduce uncertainty in decision making by economic agents, the analysis of the effect of inflation on economic growth in Canada raises two recurring questions. On the one hand, what is important, the threshold of inflation, or relative price variability? On the other hand, as the side effects of inflation on output may be different depending on the province due to the heterogeneity of the transmission mechanism of shocks (Fernandez Valdovinos and Gerling, 2011), to what extent do the Canadian monetary authorities worry about the contagion effects due to inflation in one of the provinces?

Most of previous empirical studies focus on using aggregate level data without cross-section dependence to investigate the relationship between inflation, relative price variability and economic growth. The study of the effects of inflation and relative-price variability on the real side of the economy is a clear prerequisite for determining the welfare and efficiency implications of the inflationary process. Moreover, some of these studies make use of time series data which is supposed or known to yield unreliable and inconsistent results due to the low power of the unit root test. The use of panel data may increase the sample size allowing for more accurate and reliable statistical tests. There are very few empirical works on this topic that have made an attempt to gain statistical power through the pooling of information across units. The few that have, have neglected to account for the presence of cross-section dependencies of the data. As has been shown in the literature, failure to adequately account for the presence of cross-section dependence in panel data study could lead to a serious bias problem.[4]

This paper contributes to the literature by providing new evidence on the relation between inflation, relative price variability and economic growth to a panel of Canadian provinces over the period 1981-2010. The major purpose of this paper is to econometrically assess the effects of provincial inflation and relative-price variability on economic growth by taking into consideration the assumption of cross-section dependence. To the best of our knowledge, there has never been an attempt to investigate the relationship between these important macroeconomic variables by employing disaggregated level panel data and considering the presence of cross-section dependence.

[4]Andrews (2005), Pesaran (2006) and Bai and Ng (2010)

This paper tries to fill this gap. In this spirit, we argue that the investigation of the relationship between inflation and economic growth carried out in this paper may be of great importance for monetary authorities to better under stand whether it is possible to improve the design of monetary policy in Canada given the presence of heterogeneity across the provinces and there by contribute to achieve its primary main goal (solid economic performance and rising living standards for Canadians by keeping inflation low, stable, and predictable). The remainder of the paper proceeds as follows: Section 2 presents a brief literature review and section 3 describes the data used in the current study. Section 4 outlines the econometric methodology. Section 5 analyzes results of the relationship between the inflation rate and economic growth and the impact of inflation variation on economic growth. Section 6 provides a new technique which eliminates cross-section dependency from the non-linear panel estimation. Section 7 concludes.

2 Related Literature

The issue of the nature of the relationship between the levels of inflation and output growth has been one of the most researched topics in macroeconomics both on the theoretical and empirical front.

Economists and policymakers need a clear understanding of the major channels through which inflation may affect the real economy, if they aim to minimize the adverse economic con-sequences and welfare costs of increases in the price level.

2.1 The link between inflation and relative price variability

The relationship between inflation rates and relative price variability varies across different classes of models. Firstly, menu-cost models (Rotemberg, 1983) predict inflation increases relative price variability, distort the information content of prices, and, thereby, impede the efficient allocation of resources. Secondly models which incorporate the signal extraction mechanism of Lucas (1973, 1994) predict a non-negative relationship between RPV and the absolute value of unanticipated inflation. This group includes Barro(1976), Hercowitz (1981) and Cukierman (1983). On the theoretical side, several different types of model can be used to interpret a correlation between RPV and aggregate inflation. Thirdly, the search models state that consumers accumulate information only on a subset of existing prices, but because of the deterioration in consumers' price information during inflationary periods, the stock of information a person holds declines and consequently the dispersion of prices widens (Caglayan and Filiztekin, 2003).

On the empirical side, Vining and Elwertowski (1976) have shown that the variance of the inflation rate and relative price variability are positively related over time for postwar U.S. data. Parks (1978), Fischer (1981), and others have regressed relative price variability on linear and either quadratic or absolute value terms involving the inflation rate, unanticipated inflation, or the change in the inflation rate. Following menu cost models, most empirical work on the relationship between inflation and relative price variability typically focuses on linear regressions of relative price variability on inflation. Recent researchers, namely Parsley (1996), Debelle and Lamont (1997), Aarstol (1999) and others find a significant positive impact of inflation. However, Lastrapes (2006) find that the relationship between US inflation and relative price variability breaks down in the mid-1980s, where as Reinsdorf (1994) proves that this relationship is negative during the disinflationary period of the early 1980s. A first attempt to analyze the Canadian inflation relative price variability nexus is provided by Amano et al. (1997), who examine the empirical support for the predictions of the menu-cost model using Canadian data. They find that the Canadian data, both in the context of partial correlations and standard price Phillips curve equations, are highly supportive of the predictions that arise from the menu-cost models. Lending support to search models, for example, more empirical studies suggest that the link between inflation and relative price variability is nonlinear. Several studies find that the impact of inflation on relative price variability changes between high and low inflation periods and between countries with different inflationary situations (Caglayan and Filiztekin, 2003; Becker and Nautz, 2009 and Choi, 2010). Recently, others studies apply panel threshold models and find evidence of threshold effects in the U.S. (Bick and Nautz, 2008) and in the European area (Becker and Nautz, 2010).

Staffs at the Bank have an ongoing interest in the relationship between inflation and relative price variability in Canada. Since the early 1990s, Canada has had lower trend inflation and lower inflation uncertainty. Research on the effects of these changes on relative price variability can provide evidence of the welfare cost of inflation (as described by Friedman 1977).

2.2 Inflation and economic growth

The relationship between inflation and economic growth is perhaps one of the most investigated yet controversial issues in macroeconomics on both theoretical and empirical grounds. Several theoretical studies argued that depending on its level, inflation can either promote or harm economic growth. For instance, Lucas (1973) explained that inflation allows overcoming the rigidity of nominal prices and wages. In addition, inflation can realign relative prices in response to structural changes in production during fast modernization periods. In this case inflation is quite important for economic growth. Another strand of the literature argued that inflation is detrimental for output growth in the long run. Inflation might affect output growth negatively through different channels. Friedman (1977) argues that higher inflation rates may cause a reallocation of scarce resources to unproductive activities and thus reduce output growth. Furthermore, faster inflation increases inflation uncertainty and distorts economic efficiency and thus reduces employment.

Existing empirical studies reflect different views on the relationship between inflation and economic growth. The findings differ depending on data periods and countries, suggesting that the linkage between inflation and growth is not stable. On the one hand, using a panel for 100 countries over the period 1960-1990, Barro (1995) found clear evidence that a negative relationship exists only when high inflation data is included in the sample.

But there is not enough information to argue that the same conclusion holds for lower inflation rates. The linearity of the relation between inflation and growth has been questioned by the empirical growth literature. Still, economists now widely accept the existence of a nonlinear and concave relationship between these two variables. They show that the link between inflation and growth is significant only for certain levels of inflation. Based on cross-country growth regressions, the relevance of inflation thresholds in the inflation-growth nexus has already been suggested by Fisher (1993) and Bruno and Easterly (1998). Indeed, Fisher (1993) was the first to identify a non-linear relationship where low inflation rates have a positive impact on growth, an impact that turns negative as inflation increases. Bruno and Easterly (1998) confirm the finding of a negative effect for high inflation rates but doubt the growth-enhancing effect of low inflation. They argued that in this case inflation and growth are influenced jointly by different demand and supply shocks and thus no stable pattern exists. In these papers, the inflation threshold is not estimated but imposed exogenously. More recent contributions adopt panel econometric techniques where the number and location of thresholds are not imposed but estimated from the data. For instance, Ghosh and Philips (1998) found that although inflation and growth are positively correlated at very low inflation rates (about 2 to 3 percent a year), the relationship is reversed at higher rates. Furthermore, the relationship is convex, so that the decline in growth associated with an increase in inflation from 10 to 20 percent is much larger than that associated with an increase from 40 to 50 percent. Following Blanchard, et al. (2010), the effects of inflation on growth are difficult to discern, so long as inflation remains in the single digits. As a consequence, they suggest that an inflation target of 43 might be more appropriate because it leaves more room for expansionary monetary policy in case of adverse shocks.

In Canada, Talan and Osberg (1998) and Vitek (2002) are among the first to address the relationship between inflation and economic growth. Talan and Osberg (1998) examine the relationship between the level of inflation and sectorial output growth variability. They main finding is that during this period there was, overall, no significant relationship between output growth variability and inflation in Canada. Vitek (2002) conducts an empirical investigation of dynamic interrelationships among inflation, inflation uncertainty, relative price dispersion, and output growth within a trivariate GARCH-M model. One limitation of these studies is that they have used the sectoral output growth that is not necessarily representative of the overall economy. From a social welfare perspective, the important issue is whether inflation affects output variability. Hence, in this paper we examine the link between economic growth and inflation using data of the Canadian economy.

2.3 Relative price variability and economic growth

Variability in relative prices is known to be a major channel through which inflation can induce welfare costs by impeding an efficient allocation of resources in the economy. Consequently, substantial effort has been devoted in the literature to examine the link between relative price variability (RPV) and aggregate inflation. Higher inflation uncertainty induces higher relative price variability, which, in turn, generates more variability in investment and output growth. Friedman (1977) argues that the higher the variability of inflation, the harder it becomes to extract information about relative prices from absolute prices. In his Nobel Lecture, Friedman (1977) argued that inflation may have a negative effect on output growth by increasing inflation uncertainty. Therefore, by reducing economic efficiency, greater relative price variability reduces economic growth. Blejer and Leiderman (1980) evaluate the effect of relative price variability on economic activity in the US economy and find that increased relative price variability is correlated with a decrease in the level of output and employment. Fisher (1993) argued that inflation hampers the efficient of resources due to harmful changes of relative prices. Relative prices appear to be one of the most important channels in the process of efficient decision-making. The link between RPV and economic growth is explained by the theory of rational expectations and incomplete information models. According to these two theories, a large total out-put and employment volatility implies greater price variability. Indeed, using an econometric model consistent with sticky prices and rational expectations, Taylor (1979) found a second-order Phillips curve tradeoff between fluctuations in output and fluctuations in inflation rates. He argued that this tradeoff is downward sloping, and concluded that business cycle fluctuations could be reduced only by increasing inflation variability. Cecchetti and Ehrmann (1999) argued that aggregate shocks create a tradeoff between output and inflation variability. In addition, a large variability in the price level is likely to generate monetary policies the consequences of which would be to increase uncertainty over inflation, thus affecting economic growth.

3 Data and Preliminary Analysis

3.1 The Data Set

3.1.1 Data construction and classification

In this paper, we consider annual data from ten Canadian provinces.[5] All data are (if necessary) seasonally adjusted and directly collected from Cansim (Statistics Canada) and the Bank of Canada. They cover the period 1981 to 2010, thus they include 30 years which means we have 300 points. We begin modelling the relative price variability-inflation relationship by estimating a balanced panel data model for relative price variability (rpv_{it}) using inflation (π_{it}). The relative price variability (rpv_{it}) is then constructed by the weighted average of subaggregate inflation for double-digit consumer price sectors using the standard deviation. The inflation (π_{it}) is measured as a percentage change of consumer price index. The other explanatory variables include openness and investment. Openness ($opens_{it}$), a measure of international trade, is believed to affect growth through several channels, such as access to technology from abroad, greater access to a variety of inputs for production and access to broader markets that raise the efficiency of domestic production through increased specialization. In this paper, we define openness as the ratio of exports of goods and services to GDP. We measure the level of investment in an economy as gross fixed capital formation as a share of GDP. The investment ratio ($igdp_{it}$) is generally considered to be the best variable measure of the level of investment in cross country studies since this ratio accounts for country size. Economic growth ($dgdp_{it}$) is measured as an annual percentage growth rate of GDP.

Having constructed the data we can now separate them into the different states by simply introducing the threshold effects. For the threshold value, we assume two alternatives: a known (exogenous) value and an unknown (endogenous estimate). The summary statistics of these different states together with those for each threshold and the linear specification are given inTable1.

The descriptive statistics show that economic growth is lower if inflation is above target and it becomes higher if inflation is below this target. As far as the relative price variability is concerned, it is higher if inflation is higher. So accordingly we find that lower inflation means high economic growth and lower relative price variability which could mean low inflation leads to an improvement of economic growth.

Canadian inflation has been low and stable over the last years. Since 1991 the average inflation rate across Canadian provinces has fluctuated around 2 percent. Table1 further displays the minimum and the maximum of province-specific inflation rates, indicating that inflation in Canadian provinces exceeded 6 percent and went below zero, at least for some provinces in some periods. This illustrates that inflation differentials between Canadian provinces have been modest but far from negligible. Typically, inflation rates varied in a range between 1 percent to 3.5 percent. The persistence of inflation differentials between Canadian provinces has been relatively low. Given the observed inflation differentials across provinces, it is an important feature of the panel threshold model that at each point of time different provinces are allowed to be indifferent inflation regimes.

[5] Newfoundland and Labrador, Nova Scotia, New Brunswick, Prince Edward Island, Quebec, Ontario, Manitoba, Saskatchewan, Alberta and British Columbia.

Table1: Descriptive Statistics

Variables	Linear	Endogenous threshold		
		$\gamma_\pi \in$	[1.613	; 3.323]
		d1	d2	d3
dgdp	0.02	0.027	0.026	0.017
σ_{dgdp}	0.03	0.020	0.023	0.031
$dgdp_{max}$	0.15	0.088	0.145	0.091
$dgdp_{min}$	-0.06	-0.009	-0.047	-0.063
rpv	0.02	0.015	0.018	0.021
σ_{rpv}	0.01	0.011	0.008	0.009
rpv_{max}	0.06	0.061	0.045	0.043
rpv_{min}	0.01	0.005	0.005	0.009
$\bar{\pi}$	0.033	0.011	0.023	0.058
σ_{π}	0.025	0.005	0.005	0.028
πmax	0.137	0.016	0.033	0.137
πmin	-0.005	-0.005	0.016	0.034
open	0.515	0.541	0.559	0.445
σ_{open}	0.105	0.097	0.098	0.076
$open_{max}$	0.771	0.769	0.771	0.701
$open_{min}$	0.307	0.351	0.377	0.307
igdp	0.200	0.193	0.204	0.197
σ_{igdp}	0.04	0.038	0.038	0.049
$igdp_{max}$	0.381	0.314	0.379	0.381
$igdp_{min}$	0.13	0.143	0.146	0.129
N	320	52	154	114

Notes. x stands for the mean of the respective variable, x_{max} and x_{min} for the maximum and minimum realization, while σ_X is the standard deviation, N=number of observations. D1 represents $\pi_{it} \leq$ 1.61 percent, d2 is when 1.61< $\pi_{it} \geq$ 3.32 and d3 corresponds π_{it}>3.32.

3.1.2 Correlation Analysis

Suspecting strong collinearity between some regressors, Table2 reports the pairwise correlation coefficients between all the candidate variables of the models. As can be seen, economic growth is strongly negatively correlated with the inflation rate and relative price variability; but it is positively correlated with trade openness. And the correlation between relative price variability and growth is smaller than that between inflation and growth, suggesting that economic growth is best explained by inflation. Table2 also shows that inflation and relative price variability are strongly positively correlated at the province level, suggesting that aggregate shocks (such as monetary factors) are not entirely responsible for the correlation.

Table2: Correlation Matrix across Canadian Provinces, 1981-2010

Variables	DGDP	IGDP	INF	RPV	OPEN
DGDP	1.000				
IGDP	-0.011(0.86)	1.000			
INF	-0.354[a](0.00)	-0.007(0.90)	1.000		
RPV	0.197[a](0.00)	0.117[b](0.05)	0.380[a](0.00)	1.000	
OPEN	0.102[c](0.08)	0.192[a](0.00)	-0.357[a](0.00)	-0.033(0.59)	1.000

Notes: The value in the parentheses is p-value. a, b and c a significance level of 1%, 5%, and10%.

3.1.3 Relative Price Variability

To construct our measure of Relative Price Variability (RPV), we follow the recent literature and use the measure proposed by Parks (1978). Our measure of RPV for province I (i=1,2,...,10) in period t from 1981 to 2010 (t=1,2,.......,30) is calculated as the square root of the weighted sum of square deviations of subcategory inflation around the average inflation for province i:

$$RPV_{it} = \left[\sum_{h=1}^{10} \omega_{iht}(\pi_{iht} - \pi_{it})^2\right]^{\frac{1}{2}} \qquad (1)$$

Where $\pi_{iht} = ln(P_{iht}) - ln(P_{iht-12})$ is the yearly inflation rate for subcategory h=1,2,....,10 and P_{iht} is the level of price index of the h^{th} subcategory in province I in period t. ω_{iht} denotes the province-specific weight of the h^{th} subcategory in the aggregate index so that $P_{it} = \sum_{h=1}^{10} \omega_{iht} P_{iht}$ gives the aggregate price level in province I and in period t. Hence, the inflation rates are defined as the annualized quarterly change in the relevant seasonally adjusted consumption deflator from 1981 to 2010: $\pi_{it} = ln(P_{it}) - ln(P_{it-12})$.

3.2 Preliminary Data Analysis: Panel unit root tests

All the asymptotic theories for the threshold Regression Models are for stationary regressors (see Hansen, 1996, 1999, 2000). Therefore, our specification procedures rely on the assumption that output growth, relative price variability, inflation, investment, and openness to trade are I(0) processes. In order to analyze the stationarity proprieties of the data, prior to the estimation of the linear model, we first investigate whether or not the variables appear to contain panel unit roots. Non- stationary panels have become extremely popular and have attracted much attention in both theoretical and empirical research over the last decade. A number of panel unit root tests have been proposed in the literature which include Levin et al. (2002), Breitung (2000), Im et al.(2003), Maddala and Wu (1999) and Choi (2001). The Breitung (2000) and Levin et al.(2002) panel unit root tests assume a homogeneous autoregressive unit root under the alternative hypothesis whereas Im et al.(2003) allows for a heterogeneous autoregressive unit root under the alternative hypothesis. Fundamentally, the Im et al.(2003) test averages the individual augmented Dickey-Fuller (ADF) test statistics. Both the Levin et al.(2002) and Im et al.(2003) tests suffer from a dramatic loss of power when individual specific trends are included, which is due to the bias correction. However, the Breitung (2000) panel unit root test does not rely on bias correction factors. Monte Carlo experiments showed that the Breitung (2000) test yields substantially higher power and smallest size distortions compared to Levin et al.(2002) and Im et al. (2003). Maddala and Wu (1999) and Choi (2001) suggest comparable unit root tests to be performed using the non-parametric Fisher statistic. The Fisher type test neither requires a balanced panel nor identical lag lengths in the individual regressions. The downside of the Fisher test is that the probability values need to be drawn from Monte Carlo simulations. Maddala and Wu (1999) argued that a Fisher type test with bootstrapped probability values is also an excellent choice for testing cointegration in addition to non-stationarity tests in panels. Table 3 displays the results of panel unit root tests in levels for all the variables. All tests reject the null hypothesis of a unit root in the examined series. As regards to openness to trade and investment, the tests failed to reject the null hypothesis of unit root. According to Omay and Kan (2010), this result may be due to the fact that the tests have a low power against nonlinear stationary process. From the nonlinear unit root test, we can conclude that all the variables in the paper are I(0).

Table 3: Panel Unit Root Test Results

	INFL	RPV	OPEN	IGDP
Intercept				
Levin, Lin and Chu	-10.42^{a}(0.00)	-8.41^{a}(0.00)	1.72^{b}(0.04)	2.20(0.98)
Breitung	0.99(0.84)	-3.06^{a}(0.00)	2.90(0.99)	-0.46(0.32)
Im, Pesaran and Shin	-11.02^{a}(0.00)	-8.43^{a}(0.00)	0.52(0.69)	0.50(0.69)
Fisher-ADF	141.60^{a}(0.00)	115.41^{a}(0.00)	12.85(0.88)	25.67(0.18)
Fisher-PP	196.50^{a}(0.00)	154.48^{a}(0.00)	12.63(0.89)	14.73(0.79)
Intercept+trend				
Levin,Lin and Chu	-4.81^{a}(0.00)	-10.96^{a}(0.00)	1.22(0.89)	-0.34(0.39)
Breitung	1.39(0.92)	-1.32^{c}(0.09)	-5.16^{a}(0.00)	1.69(0.95)
Im, Pesaran and Shin	-5.88^{a}(0.00)	-9.28^{a}(0.00)	-1.41^{c}(0.08)	-0.62(0.27)
Fisher-ADF	77.90^{a}(0.00)	107.51^{a}(0.00)	25.77(0.17)	24.59(0.22)
Fisher-PP	115.93^{a}(0.00)	125.33^{a}(0.00)	15.44(0.75)	29.08^{c}(0.09)

Notes: Figures in square brackets are probability values. a, b, and c represent significance at 1%, 5%, and 10% respectively. (*) Null hypothesis, the series is stationary. The maximum number of lags is set to be three. AIC is used to select the lag length. The bandwidth is selected using the Newey-West method. Barlett is used as the spectral estimation method.

4 Econometric Methodology

The main purpose of this paper is to use a threshold variable to investigate whether the relationship between inflation and economic growth through the relative price variability is different in each sample grouped on the basis of certain thresholds. The endogenous determination of threshold effects between variables is different from the traditional approach in which the threshold level is determined exogenously. If the threshold level is chosen arbitrarily, or is not determined within an empirical model, it is not possible to derive confidence intervals for the chosen threshold. The robustness of the results from the conventional approach is likely to be sensitive to the level of the threshold. The econometric estimator generated on the basis of exogenous sample splitting may also pose serious inferential problems (for further details, see Hansen (1999, 2000)).

4.1 Econometric Framework: Panel Threshold Models

Hansen (1999) developed the econometric techniques appropriate for threshold regression with panel data. Allowing for fixed individual effects, the panel threshold model divides the observations into two or more regimes, depending on whether each observation is above or below the threshold level. The general specification threshold model takes the following form:

$$y_{it} = \mu_i + \sum_{k=0}^{K-1} \beta_{k+1} x_{it} I(\gamma_k < q_{it} \le \gamma_{k+1}) + \beta_{K+1} x_{it} I(\gamma_K < q_{it} \le \gamma_{K+1}) + \varepsilon_{it} \quad (2)$$

Where subscripts I stands for the cross-sections with ($1 \le i \le N$) and t indexes time ($1 \le t \le T$).
μ_i is the province-specific fixed effect and the error term ε_{it} is independent and identically distributed (iid) with mean zero and finite variance σ_ε^2. I(·) is the indicator function indicating the regime defined by the threshold variable q_{it}, the threshold parameter γ. y_{it} is dependent variable and x_{it} the vector of explanatory variables. $\gamma_0 = -\infty$, $\gamma_{K+1} = +\infty$. Equation (2) allows for K threshold values and, thus, (K+1) regimes. In each regime, the marginal effect of $x_{it}(\beta_k)$ on y_{it} may differ.
Following the modified version of Hansen's (1999) panel threshold model proposed by Bick and Nautz (2008), we consider a discriminator constant which is not individual specific but captures a common effect for all cross-sections. According to these authors, ignoring regime dependent intercepts (δ_k) can lead to biased estimates of both the thresholds and the corresponding marginal impacts.

$$y_{it} = \mu_i + \sum_{k=0}^{K-1} (\delta_{k+1} + \beta_{k+1}) x_{it} I(\gamma_k < q_{it} \le \gamma_{k+1}) + \beta_{K+1} x_{it} I(\gamma_K < q_{it} \le \gamma_{K+1}) + \varepsilon_{it} \quad (3)$$

This formulation assumes that the difference in the regime intercepts, represented by (δ_k), is not individual specific but the same for all cross-sections. According to Bick and Nautz (2008), omission of any variable correlated with at least one regressor and the dependent variable causes biased estimates, but regime intercepts are a particularly interesting case. First, the bias can be clearly interpreted. Second, availability of regime intercepts as regressors is not an issue since they are as easily constructed as the regime-dependent exogenous regressors for a given threshold.

4.2 Estimation and Test Strategy

Estimation of the panel threshold model involves several stages. First, estimation of the parameters model requires eliminating the individual effects μ_i by removing individual-specific means and then applying the least squares sequential procedure (see Hansen (1999) for more details). Indeed, the individual specific effects are eliminated using the standard fixed-effects transformation implying for the identification of β_k and β_{k+1} that the elements of x_{it} are neither time-invariant nor adding up to a vector of ones. This case applies to regime intercepts which are usually included in each regime in threshold models in pure cross-sectional or time-series contexts. For example, in the case of two regimes, even in the presence of fixed effects it is possible to control for differences in the regime intercepts by including them in all but one regime as in the extension of the following equation:[6]

$$y_{it} = \mu_1 + (\delta_1 + \beta_1)x_{it}I(q_{it} \le \gamma) + \beta_2 x_{it}I(q_{it} > \gamma) + \varepsilon_{it} \quad (4)$$

The seminal contribution of Hansen (2000) allows us to estimate and make valid statistical inferences on the threshold. There are three statistical issues that need to be addressed in a threshold model: (1) how to jointly estimate the threshold value γ and the slope parameters; (2) how to test the hypothesis that a threshold exists and; (3) how to construct confidence intervals for γ and β. We briefly discuss each in turn. Hansen (2000) recommends obtaining the least squares estimate $\hat{\gamma}$ as the value that minimizes the concentrated sum of squared errors, $S_1(\gamma)$.
The sum of the squared error function depends on γ only through the indicator function. Hence, the minimization problem is a step procedure where each step occurs at distinct values of the observed threshold variable (π_{it}). After the threshold value γ is estimated, it is important to determine whether the threshold effect is statistically significant. In order to test the statistical significance of a threshold effect typically we would want to test the null hypothesis of no threshold effect, $H_0: \beta_1 = \beta_2$. However, since γ is only identified under the alternative ($H_1: \beta_1 \neq \beta_2$), the distribution of classical test statistics, such as the Wald and Likelihood ratio tests, are not asymptotically Chi-squared. In essence this is because the likelihood surface is flat with respect to γ, consequently the information matrix becomes singular and standard asymptotic arguments no longer apply. There are methods for handling hypothesis testing within these contexts. In some instances, we are able to bind the asymptotic distribution of likelihood ratio statistics (Davis, 1977 and 1987); alternatively their asymptotic distribution must be derived by bootstrap methods (see Hansen, 2000). The appropriate test statistic is $F_1 = \frac{S_0 - S_1(\hat{\gamma})}{\hat{\sigma}^2}$, where S_0 and S_1 are, respectively, the residual sum of squares under the null hypothesis H_0 and the alternative H_1 with $\hat{\sigma}^2$ the residual variance under the alternative hypothesis. Once the threshold effect exists, the next question is whether or not the threshold value can be known.
The null hypothesis of the threshold value is $H_0: \gamma = \gamma_0$, and the likelihood ratio statistics is $LR_1(\gamma) = \frac{S_1(\gamma) - S_1(\hat{\gamma})}{\hat{\sigma}^2}$, where $S_1(\gamma)$ and $S_1(\hat{\gamma})$ are the residual sum of squares from equation (4) given the true and estimated value, respectively. The null hypothesis is rejected for large value of LR_1. The asymptotic distribution of $LR_1(\gamma_0)$ can be used to form valid asymptotic confidence interval about the estimated threshold values. The statistics of $LR_1(\gamma_0)$ are not normally distributed and Hansen (2000) computed their no-rejection region, $c(\alpha)$, with the given asymptotic level.
He proves that the distribution function has the inverse $c(\alpha) = -2ln\left(1 - \sqrt{1-\alpha}\right)$ from which it is easy to compute the critical values. The test rejects the null hypothesis at the asymptotic level α if $LR_1(\gamma_0)$ exceeds $c(\alpha)$. The asymptotic $(1-\alpha)$ confidence interval for γ is set of values of γ such that $LR_1(\gamma) \le c(\alpha)$.[7]

5. Empirical Analysis

This paper examines the relationship between inflation, relative price variability and economic growth in Canadian provinces. The sample is derived from a disaggregated price data from1981to 2010 including ten commodities. Since Friedman (1977) made clear in his Nobel lecture that relative price variability is a direct means by which inflation can induce welfare-diminishing resource misallocation, the first part of this empirical analysis attempts to find if relative price is a channel through which inflation affects economic growth in a nonlinear fashion.

Indeed, we investigate the relationship between relative price variability and inflation by using a model with threshold effects. Once this relationship is established, the second part tries to examine the relationship between inflation and economic growth. Then we carry out some investigations on the relationship between relative price variability and economic growth. In the last part, in order to improve our results, we release the hypothesis of cross-sectional in dependence.

[6]There is no reason to limit our analysis to just two regimes. Hence, the estimation approach proposed by Hansen (1999) and extended by Bick and Nautz (2008) allows a more general specification with K thresholds (i.e. K+1 regimes)

[7]For a detailed review of the general estimation and inference strategy and the treatment of multiple thresholds the reader is referred to Hansen (1999).

5.1. Inflation and Threshold Effects on Relative Price Variability

The application of this model enables us to test for the number of inflation regimes and to estimate both the threshold levels as well as the marginal impact of inflation on RPV in the various regimes. Specifically, we consider the following threshold model for the inflation-relative price variability relationship:

$$rpv_{it} = \mu_i + \sum_{k=0}^{K-1}(\delta_{k+1} + \beta_{k+1})\pi_{it}I(\gamma_k < \pi_{it} \leq \gamma_{k+1}) + \beta_{K+1}\pi_{it}I(\gamma_K < \pi_{it} \leq \gamma_{K+1}) + \varepsilon_{it} \tag{5}$$

5.1.1 The Number of Inflation Thresholds

In a first step, we applied Hansen's (1999) sequential testing procedure for determining the number of inflation thresholds. To ensure that the threshold estimation strategy includes sufficient observations in any one of the regimes, we restrict the minimization problem to values of γ such that at least 5 percent of the observations lie in both regimes.

Table4: Test Procedure Establishing the Number of Thresholds

	Without CSD*		**With CSD**
	No regime intercepts	**Regime intercepts**	
H: no threshold			
LR1	14.247	31.605	43.837
p-value	0.019	0.000	0.000
(10%, 5%,1%critical values)	(9.017,11.645,15.583)	(10.573,11.929,16.252)	(10.213,11.628,14.295)
H: at most one threshold			
LR2	13.569	24.065	13.198
p-value	0.012	0.000	0.038
(10%,5%,1% critical values)	(9.114,10.449,13.742)	(11.103,12.734,17.027)	(10.623,12.639,17.622)
H: at most two thresholds			
LR3	17.785	6.607	9.288
p-value	0.015	0.573	0.170
(10%, 5%,1%critical values)	(9.869,11.912,19.131)	(12.496,13.951,17.339)	(10.881,12.854,17.825)

Notes. The threshold variable π_{it} is annually inflation. The sequential test procedure indicates that the number of the threshold is one.1000 bootstrap replications were used to obtain the p-values.

Following Hansen (1999), each regime is required to contain at least 53 of all observations. (*) CSD=Cross-section dependence. LR1, LR2 and LR3 give the observed value of the likelihood ratios for testing the hypothesis of no threshold, at most one threshold, at most two thresholds. The significance levels followed by LR1, LR2 and LR3 have been computed by using the bootstrap distributions of LR1, LR2 and LR3. The results indicate a clear rejection of a no-threshold effect between relative price variability and inflation in favour of a double threshold model for both without (no regime intercepts and regime intercepts) and with cross-section dependence. Specifically, the null hypothesis of a single inflation threshold in the inflation-relative price variability equation can be rejected at the 1percent significance level but at the 5 percent significance level for no regime intercepts. Thus, the data least strongly support the existence of threshold effects. According to the p-value associated to LR2, the null hypothesis of double thresholds can be rejected at the 1 percent significance level. However, the test statistic of the null hypothesis of a three thresholds cannot be rejected at 10 percent significance level for the regime intercepts, while it can be rejected at the 5 percent significance level in the no regime intercepts.

This result is consistent when taking in to account the cross-section dependency for double thresholds at the 5 percent significance level. Our results show that threshold effects of inflation can be confirmed for the nonlinear linkage between inflation and relative price variability in the Canadian provinces. Therefore, the sequential test procedure implies two thresholds and, thus, three inflation regimes in the inflation and relative price variability relationship for the Canadian provinces.

Hence when the threshold variable takes on values less than the estimated threshold values, we call this regime a low inflation regime and when the threshold variable exceeds specified threshold values, we call this regime a high inflation regime. When the inflation rates are between the two threshold values, we call this regime the moderate inflation regime.

5.1.2. Estimating the Inflation Threshold and the Slope Coefficients

The data suggest the presence of two thresholds in the function relating relative price variability and inflation. We thus estimated the following double threshold model:

$$rpv_{it} = (\delta_1 + \beta_1\pi_{it})I(\pi_{it} < \gamma_1) + (\delta_2 + \beta_2\pi_{it})I(\gamma_1 \le \pi_{it} \le \gamma_2) + \beta_3 I(\pi_{it} > \gamma_2) + \varepsilon_{it} \quad (6)$$

Table 5 presents the results for both specifications: without (column2) and with (colum3) regime intercepts. Our results suggest that the two thresholds are estimated at (γ_1=2.273 and γ_2=5.643) for the no-regime intercepts and (γ_1=1.61% and γ_2=3.32%) for regime intercepts. These findings show that inclusion of regime intercepts decreases the threshold estimate at γ_1 from 2.27 percent to 1.61 percent and for γ_2 from 5.64 percent to 3.32 percent. In addition, the upper bound of the 953 confidence interval decreases also from 6.57 percent to 3.42 percent. The most remark able observation is that, in a presence of regime intercepts, inflation rates in side the moderate inflation regime have a positive impact (0.689), and a statistically significant one, while in the no-regime intercepts this impact is negative and not statistically significant. In the low inflation regime, the marginal impact of inflation on relative price variability, without and with regime intercepts, is significantly negative (β_1=-0.441) and (β_1=-1.219) respectively. Thus, a further decline of inflation would increase relative price variability significantly. According to Jaramillo (1999), this impact of inflation rates close to zero may point to the presence of nominal downward wage and price rigidities. In the middle-inflation regime, which contains the observations for the regime of inflation rates between 2.27% and 5.64% for the no regime intercepts and 1.61% and 3.32% for regime intercepts, the impact of inflation on relative price variability is negative and no significant for no regime intercepts while in the regime intercepts, the inflation's effect is positive and significantly weaker in absolute terms. In the high inflation regime, which has the observations with inflation rates exceeding 5.64 percent (no regime intercepts) and 3.32 percent (regime intercepts), the effect is still significantly positive at the 1 percent level. Our results from the specification with a regime intercepts are in line with those by Bick and Nautz (2008) who affirm: "When inflation exceeds an upper threshold, it seems that relative price variability-increasing aspects of inflation (including e.g. menu costs and imperfect information about the price level) become eventually dominant while relative price variability-decreasing aspects of inflation have faded out".

These findings suggest that for no regime intercepts, relative price variability is the channel through which inflation can affect economic performance when inflation is below 2.27 percent and above 5.64 percent, and other wise, it is not good channel. However, for the regime intercepts, the evidence strongly supports the view that relative price variability is, for all three inflation regimes, an important channel through which inflation adversely affects economic performance, hence affects our standards living. From these findings, controlling for differences in the regime intercepts, has important implications. For example, the point estimate and upper bound of confidence interval are both substantially changed. For these reasons, we subsequently concentrate on the possibility of using the regime intercepts specification in the remainder of the paper.

Table 5: Threshold Effects of Inflation on the Relative Price Variability

	No regime intercepts	**Regime intercepts**
Threshold estimates and confidence intervals		
γ_1	2.273	1.613
95% confidence interval	[1.603 2.423]	[1.363 1.873]
γ_2	5.643	3.323
95% confidence interval	[1.613 6.573]	[3.203 3.423]
Regime dependent inflation coefficients		
β_1	-0.411[a](0.106)	-1.219[a](0.238)
β_2	-0.064(0.048)	0.689[a](0.136)
β_3	0.066[a](0.022)	0.168[a](0.022)
Regime dependent intercepts		
δ_1		0.017[a](0.003)
δ_2		-0.009[b](0.004)

Notes. Standard errors are given in parentheses. a, b and c indicate significance at the 1%, 5% and 10% level.

5.2 Analysis of the Economic Growth-Inflation Relationship

As discussed in section two, some theoretical models and empirical data predict that threshold effects are associated with a rate of inflation exceeding some critical value or below some critical value. We now allow discrete slopes to differentiate high, middle and low rates of inflation.

We then estimate the equation:
$dgdp_{it} = (\delta_1 + \beta_1 \pi_{it}) I(\pi_{it} < \gamma_1) + (\delta_2 + \beta_2 \pi_{it}) I(\gamma_1 \le \pi_{it} \le \gamma_2) + \beta_3 I(\pi_{it} > \gamma_2) + \theta' Z_{it} + \varepsilon_{it}$ (7)
where Zit the vector of control variable (see Data set in above). $I(\pi_{it} < \gamma_1)$, $I(\gamma_1 \le \pi_{it} \le \gamma_2)$ and $I(\pi_{it} > \gamma_2)$ are indicator functions which take the value of one if the term between parentheses is true, and are zero otherwise. This model specifies the effects of inflation with three coefficients: β_1, β_2 and β_3. β_1 denotes the effect of inflation below the first threshold level γ_1, β_2 denotes the effect of inflation between γ_1 and γ_2, and β_3 denotes the effect of inflation exceeding the second threshold level γ_2. The estimation results are presented in Table 6. Our investigation shows that, low to moderate inflation regime has a strongly positive effect on the economic growth rate, however, this positive relationship is not statistically significant. This result is consistent with Ragan's (2005) analysis which states that in countries that have experienced low and stable inflation, there is no significant impact on long run economic growth. Therefore, it is leacr that, in a low to moderate inflation regime an increase in inflation rates has no adverse long-run impact on Canadian living standards. At high rates of inflation, the marginal impact of additional inflation on the economic growth diminishes rapidly but is still significantly negative. In particular, our empirical results suggest that inflation distorts economic growth provided it exceeds a certain critical value. Barro (1995) estimated that a shift in monetary policy that raises the long-term average inflation by 10 percentage points per year lowers the level of the real GDP after 30 years by 4 to 7 percent. Therefore, high inflation in the long run is very harmful to Canadian provincial economies. Intuitively, our finding implies that any policy of targeting inflation rates that exceed the second threshold value will be detrimental to the economic performance of Canada. Furthermore, investment is not significant; hence there is no apparent relationship between these regressors. Openness of economy is strongly significant and positive, which corroborates theory. This finding is confirmed by Omay and Kan (2010) as well as Drukker et al. (2005) who find a similar result in the case of industrialized countries.

Table 6: Threshold Effects of Inflation on Economic Growth

Regime intercepts Threshold estimates and confidence intervals	
γ_1	1.613
95% confidence interval	[1.363 1.873]
γ_2	3.323
95% confidence interval	[3.203 3.423]
Coefficient estimates from Equation 3.8	
Regime-dependent regressors	
β_1	0.135 (0.786)
β_2	0.038 (0.394)
β_3	-0.569[a](0.133)
δ_1	-0.028[b](0.011)
δ_2	-0.024[b](0.011)
Regime independent regressors	
openness	0.175[a](0.064)
igdp	0.075 (0.085)
R^2	0.168
Observations in regime 1	52
Observations in regime 2	134
Observations in regime 3	114

Notes. Standard errors are given in parentheses. a, b and c indicate significance at the 1%, 5% and 10% level.

5.3 Analysis of the Growth-Relative Price Variability Relationship

As we mentioned in Section 2 of the literature review, the theoretical and empirical literature has suggested that the level of relative price variability might be the channel that explains the link from inflation to real economic growth. In addition, the preliminary data of Table 1 show that an increase in the inflation average corresponds to a reduction in economic growth and an increase of relative price variability.

This shows a similar pattern to that of the growth rates as inflation rises across quartiles. Furthermore, the preliminary analysis of the inflation-relative price variability relationship suggests that for Canadian provinces, inflation probably affects economic growth through the level of relative price variability. Hence, we discuss the impact of price variability on economic growth. To do this, we substitute the variable inflation by the square root of the relative price variability associated with each inflation regime.[8]

$$dgdp_{it} = (\delta_1 + \beta_1 rpv_{it})I(\pi_{it} < \gamma_1) + (\delta_2 + \beta_2 rpv_{it})I(\gamma_1 \leq \pi_{it} \leq \gamma_2) + \beta_3 I(\pi_{it} > \gamma_2) + \theta' Z_{it} + \varepsilon_{it} \quad (8)$$

Table 7 presents the estimation results of the inflation-investment relationship with threshold effects. The most striking difference between this result and the previous one is that the impact of relative price variability in the low inflation regime becomes negative, while the coefficient of relative price variability is positive for the moderate inflation regime and negative for the high inflation regime. Indeed, this finding suggests that except the first threshold, under which relative price variability has either no significant or even a negative effect on growth, the relative price variability is the important channel through which inflation adversely affects economic performance in high inflation regime. Moreover, the consideration of relative price variability as the main control variable makes our results more consistent with respect to other control variables (regime independent regressors) in terms of magnitude (from 0.175 to 0.203 for openness and 0.075 to 0.111for investment) and significance level.

[8]Taking in to account the square root (the standard deviation) is preferred to the variance for good highlight possible thresholds. See Bick and Nautz (2008).

Table 7: Threshold Effects of Relative Price Variability on Economic Growth

Regime intercepts Threshold estimates and confidence intervals	
γ_1	1.613
95% confidence interval	[1.363 1.873]
γ_2	3.323
95% confidence interval	[3.203 3.423]
Coefficient estimates from Equation 3.9	
Regime-dependent regressors	
β_1	-0.125(0.329)
β_2	0.010 (0.254)
β_3	-1.252[a](0.322)
δ_1	-0.022[b](0.009)
δ_2	-0.020[b](0.008)
Regime independent regressors	
openness	0.203[a](0.061)
igdp	0.111 (0.085)
R^2	0.150
Observations in regime 1	52
Observations in regime 2	134
Observations in regime 3	114

Notes. Standard errors are given in parentheses. a, b and c indicate significance at the 1%, 5% and 10% level.

6 *Cross-section Dependency*

Recently, the importance of taking into account cross-section correlation for testing the unit roots hypothesis has been emphasized. Pesaran's (2007) simulations show that the tests assuming cross-section independence tend to over-reject the null if cross-section correlation is present and Baltagi et al. (2007) find that when spatial autoregression is present, while first generation tests become over sized, the tests explicitly allowing for cross-sectional dependence yield a lower frequency of type I error. Indeed, the panel unit root tests employed so far have been constructed under the assumption of cross-sectional independence.

However, it has been shown in the literature that failure to account for cross-sectional dependence may cause severe size distortions and thereby invalidate estimation and inference. To overcome the bias in the panel unit root investigation, we first need to test for the presence of cross-section dependence. If cross-section dependence is confirmed in the data, stationarity should be checked by so-called second generation panel unit root tests. Several tests for cross-section dependence have been proposed in the econometric literature.

To diagnose the presence of cross-section dependence, we used the Lagrange Multiplier (LM) test, test suggested by Breusch and Pagan (1980), which is based on the squared pairwise Pear-son's correlation coefficient of the residuals. It is well known that when T>N (as is the case in this paper), this tests enjoy highly desirable statistical properties (relative to other tests) and can be used with balanced and unbalanced panel. The Breusch and Pagan (1980) test statistics 292.225, revealing that the null hypothesis of cross-section independence is rejected at the 1 percent significance level. Thus, the test rejects the null hypothesis of cross-sectional independence.

Having established that the series are cross-sectionally correlated, the next step is to implement a panel unit root test that accounts for the presence of cross-section dependence. One such test is the cross-sectionally augmented version of the Im et al. (2003) test proposed by Pesaran (2007).[9] Pesaran's test is favoured over of all others for its simplicity and clarity. Table8 displays the Pesaran (2007) statistics with an optimal number of lags (4). It is clear-cut that after accounting for cross-section dependence, the hypothesis that the series contain a unit root is confirmed at the 1 percent significance level.

Table8: Pesaran (2007) test statistics

	Series in Level		Series in first differences	
	Intercept	Intercept +trend	Intercept	Intercept+trend
INF	4.281[a]	4.108[a]	5.023[a]	5.245[a]
OPENS	-1.405	-2.014	-3.949[a]	-4.143[a]
IGDP	-1.308	-2.371[b]	-4.515[a]	-4.592[a]
RPV	-4.722[a]	-4.551[a]	-5.942[a]	-5.964[a]

Notes: Critical values for the Pesaran (2007) test are -2.56 (1%), -2.33 (5%) and -2.21 (10%) for the case of intercept only and -3.11 (1%), -2.86 (5%) and -2.73 (10%) for the intercept and a linear trend. See Table II (b, c) in Pesaran (2007). Besides, optimal lag length in these tests was selected using AIC with maximum lag order of 4. a, b, c denote significance at 1%, 5% and 10% levels.

[9]The Pesaran (2007) panel unit root test has the following form: $\Delta y_{it} = a_i + b_i y_{t-1} + c_i \bar{y}_{t-1} + \sum_{j=1}^{q} \beta_{ij} \Delta\bar{y}_{t-j} + \sum_{j=1}^{q} \delta_{ij} \Delta y_{it-j} + \varepsilon_{ij}$ where $\bar{y}_{t-1} = \frac{1}{N}\sum_{i=1}^{N} y_{it-1}$ and $\Delta\bar{y}_t = \frac{1}{N}\sum_{i=1}^{N} y_{it}$. The test is obtained as $CIPS = \frac{1}{N}\sum_{i=1}^{N} t_i(N,T)$ refers to the t-ratio of the OLS estimates of b_i

In the presence of cross-section dependence, traditional OLS-based estimations are biased and not valid. To eliminate the cross-section dependency problem, we use a method proposed by Pesaran (2006) and Omay and Kan (2010) to correct for cross-section dependency in nonlinear panel threshold regression models. This method consists in treating the equations from the different cross-section units as a system of Seemingly Unrelated Regression Equations (SURE) and then estimates the system by a Generalized Least Squares (GLS) technique. Two thresholds are detected and proved to be significant. These thresholds are estimated at 1.82 percent and 4.16 percent, this is robust to model specification and estimation approaches. At inflation rates below this threshold (1.82 percent), inflation has a significantly positive effect on relative price variability, while the magnitude of this positive impact diminishes as inflation exceeds 4.16 percent. Taking into account the cross-section dependence improves the model's explanatory power (see the coefficient of correlation R^2). Moreover, the results present in Table 9 reveal that the impact of inflation on RPV is hump-shaped. Inflation increases relative price variability if inflation is either very low(< 1.82 percent) or very high (> 4.16 percent). Between these two thresholds inflation has no real effects on the economy via its impact on relative price variability.

Indeed, for example, when inflation is moving in this interval, the Canadian monetary authorities do not consider it necessary to intervene. Therefore, threshold effects of inflation provide a further rationale for the announcement of critical levels of inflation and inflation target zones. In all these variants of the threshold model, the general conclusion remains: there is only a significant impact of inflation on relative price variability if inflation is either very low or very high, supporting price inflation stability as an outcome of optimal monetary policy. These findings suggest that during a period of moderate inflation, relative price variability is not an important channel through which inflation affects economic growth in Canadian provinces.

Table 9: Threshold Effects of Inflation on Relative Price Variability taking account cross-section dependence

Regime intercepts Threshold estimates and confidence intervals	
γ_1	1.823
95% confidence interval	[1.723 1.833]
γ_2	4.163
95% confidence interval	[3.383 4.973]
Regime dependent inflation coefficients	
β_1	0.345[a](0.042)
β_2	0.069 (0.176)
β_3	0.042[a](0.012)
Regime dependent intercepts	
δ_1	0.001 (0.001)
δ_2	-0.009[a](0.002)

Notes. Standard errors are given in parentheses. a, b and c indicate significance at the 1%, 5% and 10% level.

Table 10 indicates the results obtained with respect to the inflation and economic growth relationship when we consider cross-section dependence. An interesting finding is that for the low-inflation regime (in which the inflation rate is below 1.82 percent per year) and the middle-inflation regime (which contains the observations for the regime with inflation rates between 1.82 percent and 4.16 percent), the coefficient of inflation (β_1, β_2) are strongly positive. This result shows that a 1-percentage-point increase in inflation will cause a 0.057 to 0.098 percentage-point increase in economic growth. However, this positive relationship is only significant when inflation rates are between 1.82 percent and 4.16 percent. In the high inflation regime, which has the observations with inflation rates exceeding 4.16 percent, the coefficient of inflation is still significantly negative at the 1 percent level. The major improvement in our estimation result with a cross-section dependence correction is that the regime independent regressors not only become statistically significant with the expected sign, but also they are more consistent in terms of magnitude (from 0.175 to 0.189 for openness and 0.075 to 0.090 for investment).

Table 10: Threshold Effects of Inflation on Economic Growth taking account of cross-section dependence

Regime intercepts	Threshold estimates and confidence intervals
γ_1	1.823
95% confidence interval	[1.723 1.833]
γ_2	4.163
95% confidence interval	[3.383 4.973]
Coefficient estimates	
Regime-dependent regressors	
β_1	0.057 (0.138)
β_2	0.098[b] (0.043)
β_3	-0.143[a](0.045)
δ_1	0.002 (0.003)
δ_2	0.003[b] (0.001)
Regime independent regressors	
openness	0.189[a](0.032)
igdp	0.084[b] (0.038)
R^2	0.269
Observations in regime 1	113
Observations in regime 2	137
Observations in regime 3	50

Notes. Standard errors are given in parentheses. a, b and c indicate significance at the 1%, 5% and 10% level.

Table 11 shows the results obtained with respect to the relative price variability and economic growth relationship, when we consider cross-section dependence. The existence of two threshold levels implies that inflation can be divided into three parts. As inflation rises from 0 to1.82 percentage point, the effect on economic growth is negligible or even negative. As inflation crosses the low threshold level, it has no significant and positive impact on economic growth, up to a certain level. When inflation crosses the second threshold level (4.16 percent), the marginal impact is negative and significant. Unlike in the case of inflation-growth, the major difference is the regime independent regressors are not only become significance level and respect expected sign but are consistent in terms of magnitude.

Table 11: Threshold Effects of Relative Price Variability on Economic Growth taking account of cross-section dependence

Regime intercepts Threshold estimates and confidence intervals	
γ_1	1.823
95% confidence interval	[1.723 1.833]
γ_2	4.163
95% confidence interval	[3.383 4.973]
Coefficient estimates	
Regime-dependent regressors	
β_1	-0.036(0.126)
β_2	0.071 (0.089)
β_3	-0.824^a(0.194)
δ_1	0.001 (0.002)
δ_2	0.003^b (0.001)
Regime in dependent regressors	
openness	0.182^a(0.029)
igdp	0.090^b (0.035)
R^2	0.295
Observations in regime 1	113
Observations in regime 2	137
Observations in regime 3	50

Notes. Standard errors are given in parentheses. a, b and c indicate significance at the 1%, 5% and 10% level.

7 Conclusion

This paper provides new evidence on the nonlinear relationship between inflation and economic growth through relative price variability. Recent empirical analysis suggests a negative nonlinear inflation-growth relationship. Many papers addressing this issue explain this nonlinearity with threshold effects. That is, below a specific threshold value, inflation is found to have a statistically non significant small negative or positive effect on economic growth, where as above it, the effect becomes negative and statistically significant. To confirm or not the general consensus among economists that inflation produces welfare costs and price stability should be the prior goal of monetary policy, we follow Hansen (1999) and Omay and Kan (2010) and developed a panel threshold model with cross-section dependence. We first investigate the relationship between inflation and relative price variability. This allows us to verify if relative price variability should be an important channel through which inflation adversely affects Canadian provinces economic performance. The empirical results show the existence of a double threshold (1.61 percent and 3.32 percent), that divides the inflation range into three categories, i.e., low inflation, moderate inflation and high inflation. These threshold effects of inflation can be confirmed for the inflation-relative price variability nexus in the Canadian provinces. Examining the relationship between inflation and economic performance, we find that for low and moderate inflation regimes the marginal effect of inflation is strongly positive; however this positive relationship is not significant. In the extremely high inflation regime the marginal effect is significantly negative at the 1 percent level. Using relative price variability as a channel through which inflation affects economic growth, we find the same result except that for the low inflation regime the marginal effect is negative. In addition, our results are more consistent with respect to other control variables (openness and investment) in terms of magnitude and significance level.

All these findings are based on the assumption of independence over the cross-section units. However, we see from our analysis that this assumption is violated. Therefore, we do a Breusch and Pagan (1980) test to diagnose for the presence of cross-section dependence. This test reveals the presence of cross-section dependence, thus the traditional estimations are not efficient and not valid. To over come this cross-section dependence problem, we apply the SURE-GLS approach. The results of our estimation indicate the existence of a double threshold (1.82 percent and 4.16 percent). As Freidman (1977), our findings suggest that the relative price variability is an important channel through which inflation adversely affects economic performance in Canadian provinces.

Furthermore, taking into account cross-section dependence improves the model's explanatory power (see the coefficient of correlation R^2) and all the control variables are more robust in terms of significance level. Inflation below the first threshold (1.82 percent) effects economic growth in significantly and positively; at moderate rates of inflation, between the two threshold levels (1.82 percent and 4.16 percent), the effect of inflation is significant and strongly positive and at high rates of inflation, above the second threshold (above 4.16 percent), the marginal impact of additional inflation on economic growth is significantly negative.

These findings provide some policy implications. On the basis of this study, it is desirable to keep inflation in the moderate inflation regime and therefore the Bank of Canada should concentrate on those policies which keep the inflation rate between 1.82 percent and 4.16 percent because it maybe helpful for the achievement of sustainable economic growth and to improve the living standards of Canadian provinces. This information gives a very important signal for Canadian policymakers to impose new policies to provide economic stabilization to the Canadian provinces. Our results confirm the claims of Blanchard et al. (2010, page 11) who argue that: "Should policymakers therefore aim for a higher target inflation rate in normal times, in order to increase the room for monetary policy to react to such shocks. To be concrete, are the net costs of inflation much higher at, say, 4 percent than at 2 percent, the current target range? Is it more difficult to anchor expectations at 4 percent than at 2 percent? " In other words, the effects of inflation on growth are difficult to discern, so long as inflation remains in the single digit range. As a consequence, suggest that an inflation target of 4 percent might be more appropriate because it leaves more room for expansionary monetary policy in the case of adverse shocks.

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Appendix A: The Lagrange Multiple Test

Breusch and Pagan (1980) proposed a Lagrange Multiplier (LM) statistic for testing the null of zero cross equation error correlations, which is defined as

$LM = T\sum_{i}^{N-1}\sum_{j=i+1}^{N}\hat{\rho}_{ij}^{2}$ where $\hat{\rho}_{ij}$ is the sample estimate of the pair-wise correlation

$$\hat{\rho}_{ij} = \hat{\rho}_{ji} = \frac{\sum_{t=1}^{T} e_{it}e_{jt}}{\left(\sum_{t=1}^{T} e_{it}^{2}\right)^{\frac{1}{2}}\left(\sum_{t=1}^{T} e_{jt}^{2}\right)^{\frac{1}{2}}}$$

e_{it} is the OLS estimate of terms of error. LM is asymptotically distributed as Chi-squared with

$\frac{N(N-1)}{2}$ degrees of freedom under the null hypothesis as T > N.

Appendix B: Tables

Appendix B.1: Distribution of observations of both sides of the thresholds.

ariables	Endog. thres.		
	[1.613		3.323]
	d1	d2	d3
AB	5	13	12
BC	5	15	10
MA	3	14	13
NB	8	12	10
NFL	6	15	9
NS	4	15	11
PEI	5	13	12
ON	5	12	13
QC	7	11	12
SAS	4	14	12
Total	52	13	114

Notes.: Alberta=AB; British Columbia=BC; Manitoba=MA; New Brunswick=NB; Newfoundland and Labrador=NFL; Nova Scotia=NS; Prince Edward Island=PEI; Ontario=ON; Quebec=QC and Saskatchewan=SAS.

Source: Author's calculation. d1 represents $\pi_{it} < 1.61$ percent, d2 is when $1.61 < \pi_{it} \leq 3.32$ and d3 corresponds $\pi_{it} > 3.32$.