

## ANALYSIS OF THE STABILITY OF INFLATION IN INFLATION TARGETING COUNTRIES VIA CONTROL CHARTS

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**Abstract:** While inflation targeting (IT) has been adopted by a few countries as a monetary policy tool chiefly for inflation fighting purposes, the debate relative to its effect on making a difference on actual inflation level of the adopting country has been waging with no end in sight. A number of authors have attempted to address the issue with usually qualitative means. In this paper, we analyze the stability of inflation levels before and after the adoption of IT with the help of ‘control charts.’ Control charts tell us when and in what fashion processes deviate from stability, allowing us to take timely and appropriate action to keep the process on course. Our findings show that the instability in inflation levels has been reduced in the post adopted era.

**Keywords:** Inflation Targeting, Control Charts

### 1. INTRODUCTION

The unbearable costs of inflation led many countries to look for ways in curbing the impact of the fast changing prices on the market participants. New Zealand was the first country to come up with the actual practice of a new monetary policy tool called inflation targeting (IT). IT largely took the shape of a range rather than a point targeted by the central bankers to achieve. A number of countries, both in the industrialized as well as the developing world, soon followed the suit. By and large, the outcome was lauded as “successful.” In other words, IT adopting countries usually observed lower levels of inflation compared to their history. Even the US was speculated to have switched to an explicit IT adoption system under the Federal Reserve Chairman Ben Bernanke (Meyer 2004), though it did not happen for a variety of reasons. In all fairness, the evidence to prove the impact of the adoption of the new policy mechanism is still debatable.

Bernanke (2003) argues that because none of the IT adopting countries have switched back, IT must be considered successful by these countries. Likewise, Johnson (2002) shows that IT adoption has positively affected the behavior of market participants in the relevant countries, especially in terms of expectations. Given that expectations are among the most important variables to reign in an inflationary spiral (Bernanke 2003, Huh 1997, Meyer 2004, Piger and Thornton 2004, Kadioglu, Ozdemir and Yilmaz 2000, Bangko Sentral ng Pilipinas 2001, Woodford 2004 and Mishkin 2007), Johnson’s finding could provide an important clue to the success of IT adoption. However, recently, Honda (2000), Genc *et al.* (2007), and Genc (2009) conclude that the inflation levels before and after the IT adoption did not matter in IT adopting countries, thus refuting the success of IT.

Admittedly most of the studies on this topic are qualitative in nature (Bardsen *et al.* 2003, Choi *et al.* 2003, Genc *et al.* 2007, and Genc 2009), the jury is still out based on the findings of the quantitative studies. Needless to say, the differences in coverage periods and economies make a reliable comparison highly difficult. Therefore, in this paper, we try to implement an international comparison of the performance of a few IT adopting countries in a quantitative perspective. Countries considered are Canada, New Zealand, Sweden, and the UK. And the analysis tool used is the control charts.

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The rest of the paper is organized as follows. The next section details the methodology and data used in this study. The section after next presents the statistical results and the last section discusses the former and concludes this study.

## 2. METHODOLOGY AND DATA

We make use of the so-called control charts to gauge the impact of IT adoption on the inflation level of the adopting countries. To our knowledge, this statistical tool has not been used in this context, i.e. to test the statistical characteristics of control charts, or even any topic in macroeconomic econometrics. That is why; our research can be considered as one of the first attempts to introduce control charts into macroeconometrics. Since control charts are not widely employed in macroeconomics, we provide a brief background on the tool in question.

Control charts are “windows” into process behavior and they are extensively used to monitor statistical control of a process. They allow users to compare process behavior against the frame of reference, or model, called *stability*. Control charts tell the users when and in what fashion processes deviate from stability, allowing us to take timely and appropriate action to keep the process on course. Although the concepts of statistical control and control charts were developed in the context of manufacturing, their applications were also found in non-manufacturing/service industry as well.

The first control chart was developed in the 1920s by Dr. Walter A. Shewhart of the Bell Telephone Laboratories. Shewhart (1926, 1931, 1939) state that regardless of how well designed or carefully maintained a production process, a certain amount of inherent or natural variability will always exist. This natural variability is the cumulative effect of many small and unavoidable causes. In the framework of statistical quality control, this natural variability is often called a “stable system of chance causes.” A process that is operating with only chance causes of variation present is said to be in statistical control since the chance causes are an inherent part of the process. Other kinds of variability may occasionally be present in the output of a process and this variability in key quality characteristics usually arises from three sources: improperly adjusted machines, untrained operators’ errors, or defective raw materials. Such variability is generally large when compared to the natural variability and it usually represents an unacceptable level of process performance. These sources of variability that are not part of the chance cause pattern are “assignable causes” and a process that is operating in the presence of assignable causes is said to be out of control.

The basic principles behind any control chart can be explained as follows. Figure 1 depicts a typical control chart, which is a graphical display of a quality characteristic that has been measured or computed from a sample versus the sample number or time. The chart contains a center line (CL) that represents the average value of the quality characteristic corresponding to the in-control state. (That is, only chance causes are present.) Two other horizontal lines, called the upper control limit (UCL) and the lower control limit (LCL), are also shown on the chart. These control limits are chosen so that if the process is in control, nearly all of the sample points will fall between them. As long as the points fall within the control limits, the process is assumed to be in control, thus, warranted no further action. However, a point that plots outside of the control limits is interpreted as evidence that the process is out of control, and investigation and corrective action are required to identify and eliminate the assignable cause or causes responsible for this behavior. The sample points on the control chart are connected with straight-line segments so that it is easier to visualize how the sequence of points has evolved over time: temporary/permanent shift in the mean level and temporary/permanent increase or decrease in variability of the quality characteristic can be readily detectable.

In addition, even if all the points fall within the control limits, if they behave in a systematic or nonrandom manner, then this could be an indication of an out-of-control process. For example, if 18 of the last 20 points fall above the center line but below the upper control limit and only two of these points plotted below the center line but above the lower control limit, this nonrandom phenomenon arouse suspicion about the assumption that the process is in control since all the plotted points should have an essentially random pattern. Methods for looking for sequences or nonrandom patterns can be applied to control charts as an aid in detecting out-of-control conditions. Usually, there is a reason why a particular nonrandom patter appears on a control chart, and if it can be found and eliminated, process performance can be improved. Details on the different sets of decision rules for detecting systematic or nonrandom patterns on control charts are discussed further in Nelson (1984) and Western Electric (1956).

Based on the above (Shewhart) charting philosophy, different types of univariate control charts evolved, depending on the type of quality characteristic that they are supposed to monitor and control. Tables 1a and 1b list the different types of commonly-used (Shewhart) control charts for quality characteristics: variables and attributes, their purposes, and how the control limits are determined. Note that these widely available in any quality-related texts: Duncan (1986), Gitlow *et al.* (1994), Vardeman and Jobe (1998), Montgomery (2005) *inter alia*.

A major drawback of the above-mentioned Shewhart control charts is that it is not very effective in detecting shifts of small magnitudes. Montgomery (2005) point out that the Shewhart control chart for sample averages is very effective in detecting shifts with magnitudes of at least one-and-a-half times the standard deviation. For smaller shifts, it is not as effective and thus, alternatives are needed when shifts of smaller magnitudes are of interest. The cumulative-sum (CUSUM) control charts were first proposed by Page (1954) to monitor and control process mean. Subsequent studies by Page (1961), Johnson and Leone (1962a, 1962b, 1962c), Ewan (1963), Lucas (1976, 1985), Lucas and Crosier (1982), Hawkins (1981, 1993a), Gan (1991, 1993), and Woodall and Adams (1993) extend the use of CUSUM control charts to monitor and control process variability, and even binomial and Poisson variables for modeling process fallout and nonconformities, respectively.

Another alternative to the Shewhart control chart when the detection of small shifts is of interest is the exponentially weighted moving-average (EWMA) control chart. It was first introduced by Roberts (1959) to monitor process mean and extension of its use has been made to monitor process standard deviation by Crowder and Hamilton (1992) and MacGregor and Harris (1993). Hunter (1986), Crowder (1987a, 1989), Ng and Case (1989), Lucas and Saccucci (1990) *inter alia* provide a good discussion on details of the properties of the EWMA control chart.

In situations where simultaneous monitoring or control of two or more related quality characteristics is necessary, there is a need for multivariate controls charts to do the job since independent monitoring of the different quality characteristics can lead to very misleading results. Montgomery (2005) highlights the former using an example where a bearing has both an inner diameter and an outer diameter that together determine the usefulness of the part. If the two quality characteristics (diameters) were monitored independently, this analysis will produce a Type I error larger than it is supposed to be.

Hotelling (1947) pioneers the works in multivariate quality control where he applied his methodology to bombsight data during the Second World War. Subsequent works dealing with control procedures for several related variables include Hicks (1955), Jackson (1956, 1959, 1985), Alt (1985), Hawkins (1991, 1993b), Mason *et al.* (1992, 1995), Lowry and

Montgomery (1995), Prins and Mader (1997), and Vargas (2003). Multivariate versions of the CUSUM and EWMA (or an MEWMA) control charts are widely discussed in Crosier (1988) and Pignatiello and Runger (1990), and Lowry *et al.* (1992) and Bodden and Rigdon (1999), respectively.

In this paper, we would like to apply the control charts for individual measurements (or an *I* chart) to detect shifts in the mean inflation rates of a few countries, namely, UK, New Zealand, Canada and Sweden. The control chart for individual measurements was proposed by Nelson (1982) to monitor and control the process in the following situations:

1. Automated inspection and measurement technology is used, and every unit manufactured is analyzed;
2. Repeat measurements on the process differ only because of laboratory or analysis error, particularly common in chemical processes;
3. The data become available very slowly, and waiting for a larger sample will be impractical or make the control procedure too slow to react to problems. This often happens in nonproduct situations; for example, accounting data may become available only monthly.

Note that the above third situation suits our study in this paper, that is, to detect shifts in the inflation rates.

The *I* chart is just a sequence/time series plot of the individual values with the three horizontal lines upper control limit (UCL), center line (CL), and lower control limit (LCL) superimposed onto it. Any data point that falls beyond UCL or LCL indicate that there is a significant shift in the mean of the inflation rate. The control limits for the *I* chart are  $UCL = \mu + 3\sigma$  and  $LCL = \mu - 3\sigma$ , with  $CL = \mu$ . Since the parameters  $\mu$  and  $\sigma$  are unknown most of the times, they are estimated by  $\bar{\bar{X}}$  and  $\frac{\overline{MR}}{d_2}$ , respectively, where  $\overline{MR}$  is the average moving ranges ( $MR_i$ ), i.e.,

$$\overline{MR} = \frac{1}{n-1} \sum_{i=2}^n MR_i$$
 and  $d_2$  is a one of the control chart constraints (available in any above-mentioned quality related texts: Duncan 1986, Gitlow *et al.* 1994, Vardeman and Jobe 1998, Montgomery 2005).

Just like the range chart (*R* chart) or standard deviation chart (*s* chart) which is used in conjunction with the mean chart ( $\bar{\bar{X}}$  chart) to monitor and control the variability and mean of the process, respectively, the moving range chart (*MR* chart) is used to monitor and control the variability. The control limits for the *MR* chart are  $UCL = 3.686\sigma$  and  $LCL = 0$  and again, since the parameter  $\sigma$  is unknown most of the times, it is estimated by  $\frac{\overline{MR}}{d_2}$ . For refinements

of the above control limits of the *I* and *MR* charts, please refer to Crowder (1987b) for details.

Quarterly data from 1960 to 2004 (base year 2000) on consumer price indexes (CPI) for all items for Canada, New Zealand, Sweden and the United Kingdom from the IMF International Financial Statistics (IFS) database were collected and the inflation rates for each country,  $\pi$ , are produced from the CPI,  $P_t$ , as  $\pi_t = \ln(P_t / P_{t-1})$ .

### 3. STATISTICAL RESULTS

The statistical results of the experiments mentioned before are shown in Figures 2-5. Specifically in Figure 2, a control chart for the New Zealand's inflation is presented. New Zealand started to make use of an IT policy as of 1990.1. The closest shock picked up by the control chart is the inflation value corresponding to 1986.3. There are of course break points

observed prior to this date. All these mean that by the time the New Zealand monetary authorities adopted an inflation targeting policy the country has already attained a stable inflation level. As a matter of fact, for sustainable IT policies, public has to be convinced ahead of time that the monetary authorities are capable of maintaining the announced targets without cheating down the road. In the latter case, the public would have the incentive to form expectations in contravention to authorities' efforts to reduce inflation. That would beat the whole purpose of adopting such a policy in the first place.

As one of the pioneers of IT policy adoption in the world, Canada switched to an IT framework in 1991.1. The closest statistically significant break point observed in the control chart for the Canadian inflation took place in 1990.4. This is immediately before the switch to the new policy. Under these circumstances, Canadian case can be considered as an indicator of a shock in inflation once the IT is adopted. However, it is worth mentioning that the 1990.4 break point is preceded by a long lull in inflation levels all the way back to 1982.1. Then, we cautiously say that the adoption of IT did not necessarily change the behavior of inflation in Canada, either.

The control chart for the UK inflation is shown in Figure 4. Given that the UK adopted an IT policy in 1992.4, one can also treat the behavior of inflation in this country the same as before since the shock prior to the adoption date took place in 1990.1. And even prior to this shock the inflation was stable.

As the latest adopter of an IT framework, Sweden, too, follows the same policy adoption process, i.e. switching to a new monetary policy making paradigm only after a stable experience with the inflation in the country.

All in all, based on our findings, it is difficult to say that there is statistical evidence for a structural break (break point, shock) in the level of inflation at the time of the IT adoption date.

#### **4. DISCUSSION OF THE STATISTICAL RESULTS AND CONCLUSIONS**

Not only the role of the monetary policy but also the form thereof has long been the subject matter of a heated discussion in the academic as well as policy circles. The heavy cost of inflation on a large segment of society led the authorities to find ways to alleviate this pain. As the Keynesian Coordination failure theory would like us believe the self-fulfilling prophecies of good and bad times lead to business cycles in the overall economy. If, in that sense, economic agents expect that the central will inflate the economy, despite the assurances to the contrary from the central bank, they will seek higher wage contracts. That will eventually make producers pass the prices onto the final goods. This is inflation! The fear of inflation has already been materialized! Even if the central bankers did not inflate the economy. That is why some researchers are of the opinion that the biggest challenge for the monetary policy makers is the control of expectation formation.

Therefore, inflation targeting is considered as just the right policy tool to tackle the expectation formation problem. A promise of low inflation by the central bank has credibility in the eyes of public, especially if it is accompanied by penalty clauses against the central bank in case of a failure. This is the reason why the levels of inflation got lower in countries where IT was adopted as a framework for monetary policy making. However, as the literature review points out, the researchers do not all agree that the mere adoption of such a policy should take the full credit of the "success" in the lower levels of inflation.

We, however, beg to differ. By analyzing pretty much the same set of countries with Honda (2000), Genc *et al.* (2007), and Genc (2009), we arrive at the same finding that inflation targeting cannot be exclusively credited for the achievement attained in the inflation levels.

Though all these studies make use of different statistical tools and methods, the same conclusion is reassuring. We believe that the reduction in the inflation level in these countries were probably due to low inflation levels observed in these economies prior to the actual adoption date. This does not mean that the IT framework did not help in keeping inflation lower in these countries. On the contrary, it probably provided the much needed assurance on the part of the central bank to signal its commitment to a stated policy objective. That is why, there was sort of a ‘social contract’ between the policy makers and the public on the premise of a certain level of inflation. What we show, however, is that there was no magic of IT in reducing inflation levels in these countries simply because central bankers switched to this policy agenda. We provide structural evidence for our findings while further contributing to the quantitative IT literature. In particular, we introduce to macroeconometrics literature the so-called control charts idea to detect the changes in the mean of the level of a variable with a special example of inflation rates. To our knowledge, this is a first in macroeconometrics field.

**TABLES**

**Table 1a** Different types of Shewhart control charts for variables.

Types of Charts	Quality Characteristics	Purpose	Standards given Control Limits <sup>a</sup> (parameters known)	Retrospective Control Limits <sup>b</sup> (parameters unknown)
$\bar{X}$ chart	Sample means	To monitor and control the mean value of a variable	$UCL = \mu + 3 \frac{\sigma}{\sqrt{n}}$ $CL = \mu$ $LCL = \mu - 3 \frac{\sigma}{\sqrt{n}}$	$UCL = \bar{\bar{x}} + A_2 \bar{R} \text{ or } \bar{\bar{x}} + A_3 \bar{s}$ $CL = \bar{\bar{x}}$ $LCL = \bar{\bar{x}} - A_2 \bar{R} \text{ or } \bar{\bar{x}} - A_3 \bar{s}$
R chart	Sample ranges	To monitor and control the variability of a variable	$UCL = D_2 \sigma$ $CL = d_2 \sigma$ $LCL = D_1 \sigma$	$UCL = D_4 \bar{R}$ $CL = \bar{R}$ $LCL = D_3 \bar{R}$
s chart	Sample standard deviations	To monitor and control the variability of a variable	$UCL = B_6 \sigma$ $CL = c_4 \sigma$ $LCL = B_5 \sigma$	$UCL = B_4 \bar{s}$ $CL = \bar{s}$ $LCL = B_3 \bar{s}$
$s^2$ chart	Sample variances	To monitor and control the variability of a variable	$UCL = \frac{\sigma^2}{(n-1)} \chi_{\alpha/2; n-1}^2$ $CL = \sigma^2$ $LCL = \frac{\sigma^2}{(n-1)} \chi_{1-\alpha/2; n-1}^2$	$UCL = \frac{\bar{S}^2}{(n-1)} \chi_{\alpha/2; n-1}^2$ $CL = \bar{S}^2$ $LCL = \frac{\bar{S}^2}{(n-1)} \chi_{1-\alpha/2; n-1}^2$

<sup>a</sup>Values of the process parameters such as  $\mu$  and  $\sigma$  are obtained based on past experience with a process, engineering standards, or other considerations made prior to a particular application specify what values should be used.

<sup>b</sup>In circumstances where one has no information on a process outside a series of samples, values of the process parameters such as  $\mu$  and  $\sigma$  are estimated by their sample counterparts,  $\bar{\bar{x}}$  (average of the sample means) and  $\bar{R}$  (average of the sample ranges) or  $\bar{s}$  (average of the sample standard deviations), respectively, assuming the process is stable.

<sup>a&b</sup>Values of the above control chart constraints:  $A_2, A_3, d_2, D_1, D_2, D_3, D_4, c_4, B_3, B_4, B_5,$  and  $B_6$  are readily available in any quality related texts.

**Table 1b** Different types of Shewhart control charts for attributes.

Types of Charts	Quality Characteristics	Purpose	Standards given Control Limits <sup>a</sup> (parameters known)	Retrospective Control Limits <sup>b</sup> (parameters unknown)
<i>p</i> chart	Sample fraction of defectives/nonconforming units	To monitor and control the fraction of nonconforming units per batch, per day, per machine <i>p</i> . (used when the occurrence of nonconforming units is not rare; $np > 5$ )	$UCL = p + 3\sqrt{\frac{p(1-p)}{n}}$ $CL = p$ $LCL = \text{Max} \left[ 0, p - 3\sqrt{\frac{p(1-p)}{n}} \right]$	$UCL = \bar{p} + 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}}$ $CL = \bar{p}$ $LCL = \text{Max} \left[ 0, \bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n}} \right]$
<i>np</i> chart	Number of defectives/nonconforming units	To monitor and control the number of nonconforming units per batch, per day, per machine <i>np</i> . (used when the occurrence of nonconforming units is not rare; $np > 5$ )	$UCL = np + 3\sqrt{np(1-p)}$ $CL = np$ $LCL = \text{Max} \left[ 0, np - 3\sqrt{np(1-p)} \right]$	$UCL = n\bar{p} + 3\sqrt{n\bar{p}(1-\bar{p})}$ $CL = n\bar{p}$ $LCL = \text{Max} \left[ 0, n\bar{p} - 3\sqrt{n\bar{p}(1-\bar{p})} \right]$
<i>c</i> chart	Number of defects/nonconformities	To monitor and control the number of nonconformities per inspection unit <i>c</i> (used when the occurrence of nonconformities is rare)	$UCL = c + 3\sqrt{c}$ $CL = c$ $LCL = \text{Max} \left[ 0, c - 3\sqrt{c} \right]$	$UCL = \bar{c} + 3\sqrt{\bar{c}}$ $CL = \bar{c}$ $LCL = \text{Max} \left[ 0, \bar{c} - 3\sqrt{\bar{c}} \right]$
<i>u</i> chart	Average number of defects/nonconformities	To monitor and control the average number of nonconformities per inspection unit <i>u</i> (used when the occurrence of nonconformities is rare)	$UCL = u + 3\sqrt{\frac{u}{n}}$ $CL = u$ $LCL = \text{Max} \left[ 0, u - 3\sqrt{\frac{u}{n}} \right]$	$UCL = \bar{u} + 3\sqrt{\frac{\bar{u}}{n}}$ $CL = \bar{u}$ $LCL = \text{Max} \left[ 0, \bar{u} - 3\sqrt{\frac{\bar{u}}{n}} \right]$

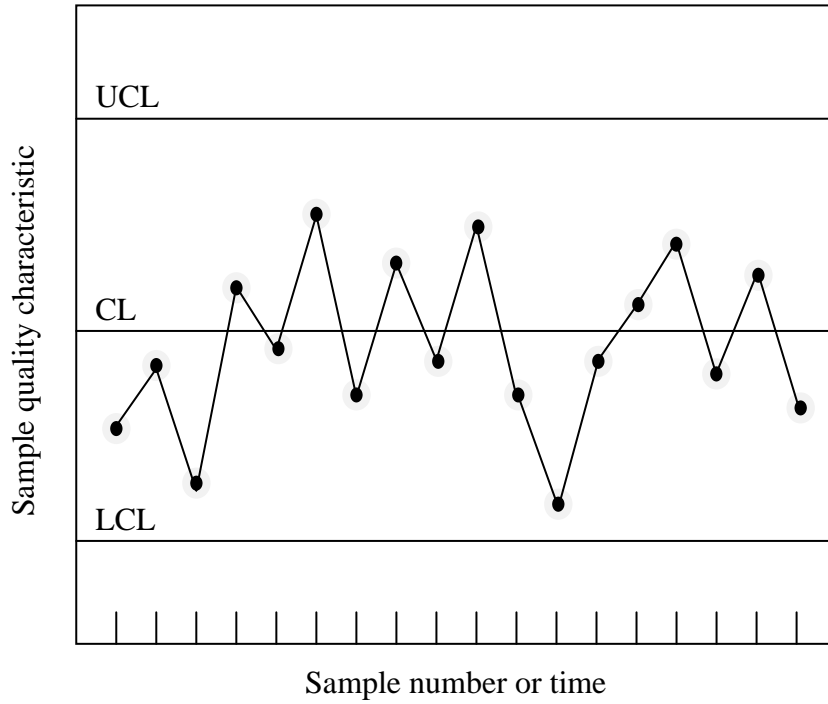
<sup>a</sup>Values of the process parameters such as *p*, *c*, and *u* are obtained based on past experience with a process, engineering standards, or other considerations made prior to a particular application specify what values should be used.

<sup>b</sup>In circumstances where one has no information on a process outside a series of samples, values of the process parameters such as *p*, *c*, and *u* are estimated by their sample counterparts,  $\bar{p}$  (average of the sample proportions),  $\bar{c}$  (average number of nonconformities per inspection unit) or  $\bar{u}$  (average of the average number of nonconformities per inspection unit), respectively, assuming the process is stable.



**FIGURES**

**Figure 1:** A typical control chart



**Figure 2:** A control chart for New Zealand

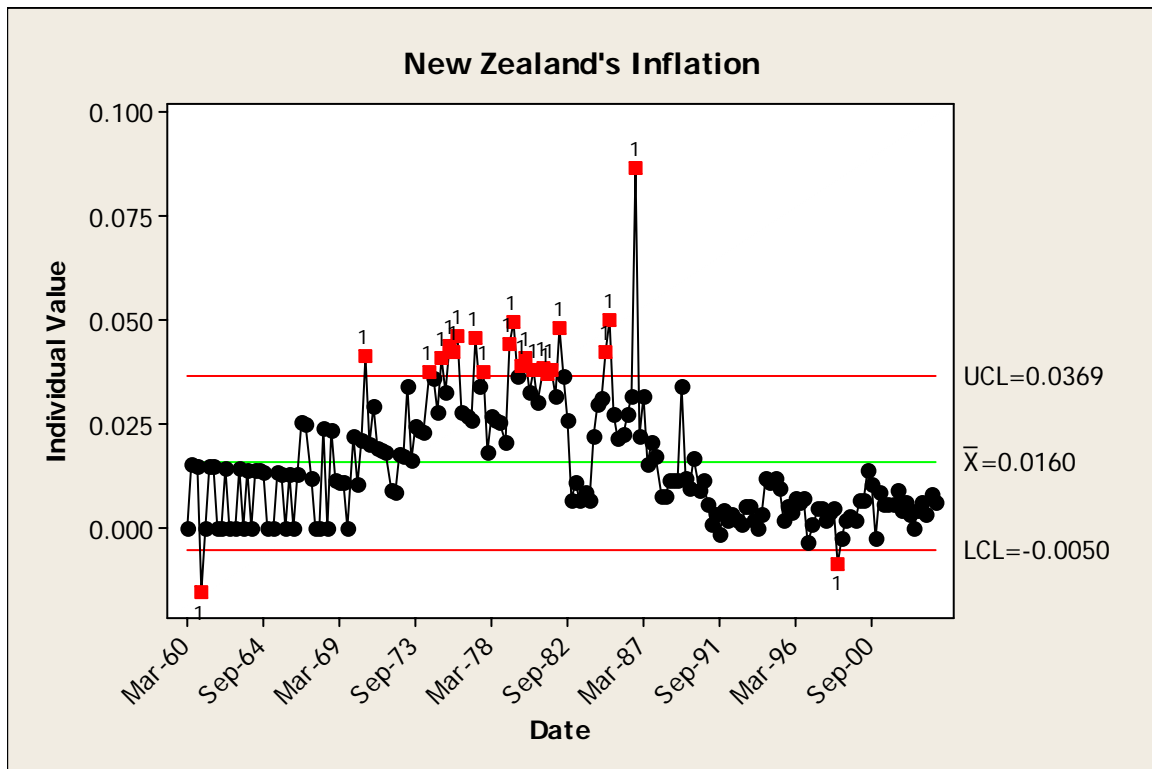


Figure 3: A control chart for Canada

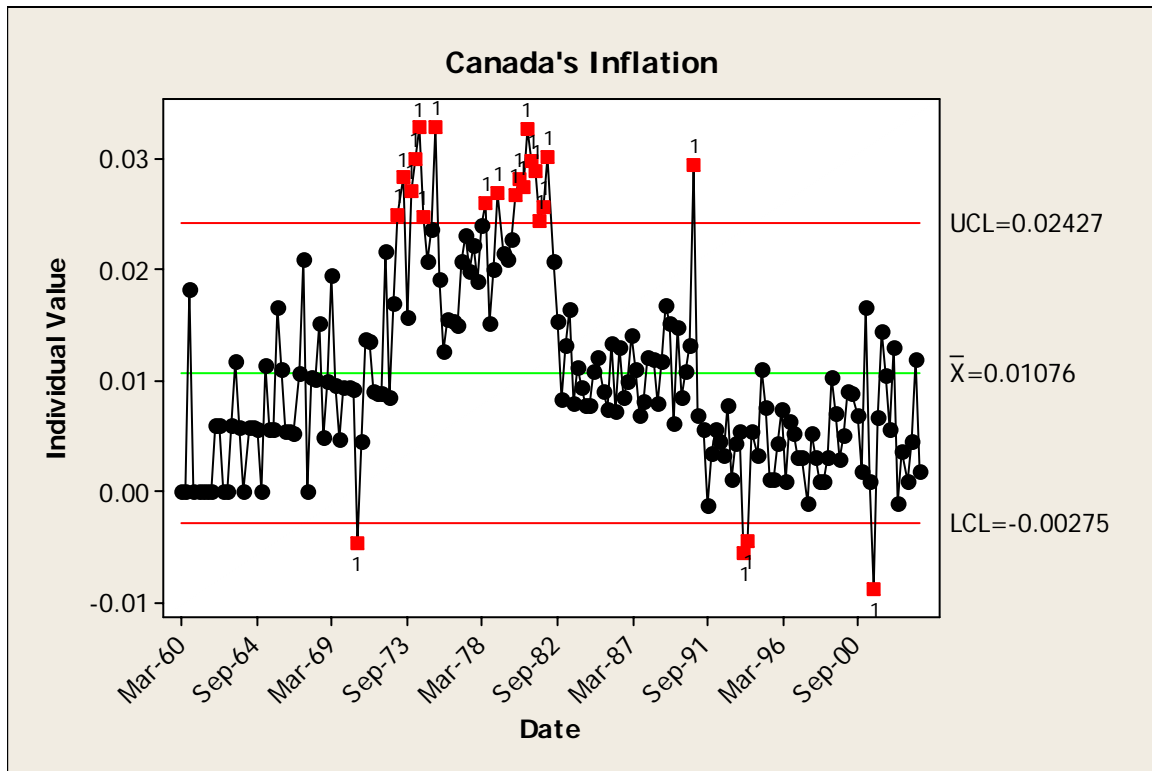


Figure 4: A control chart UK

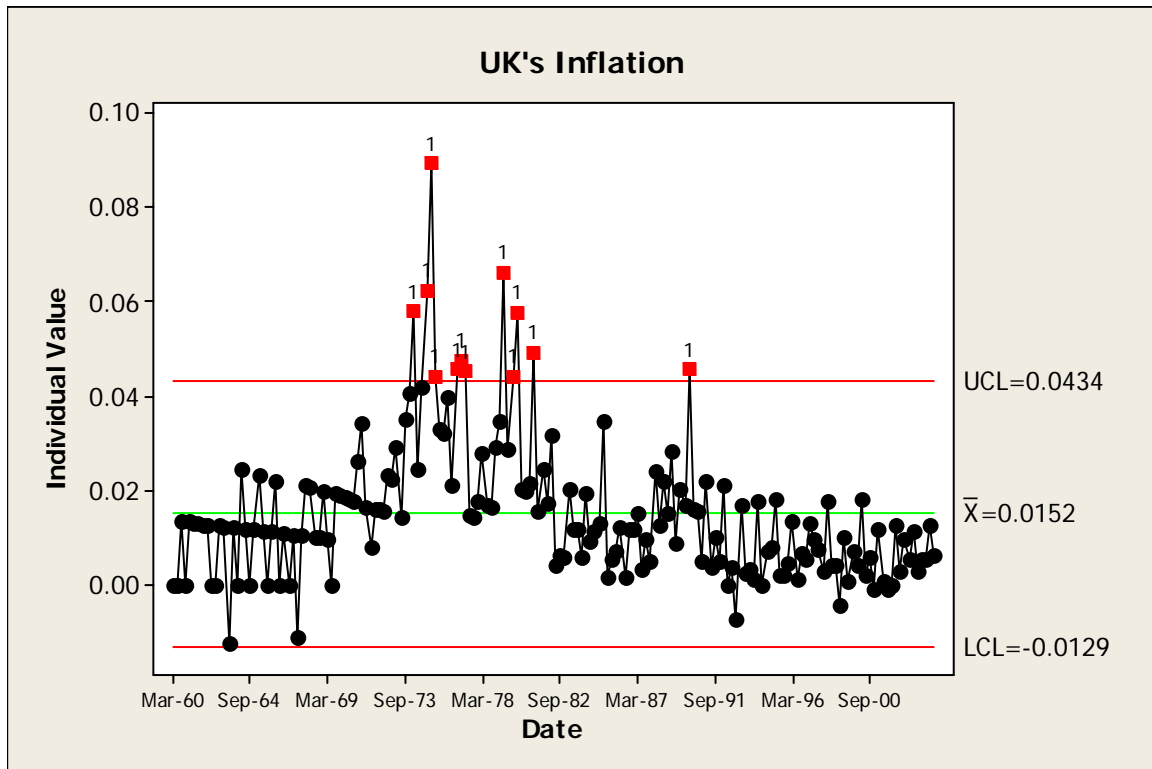
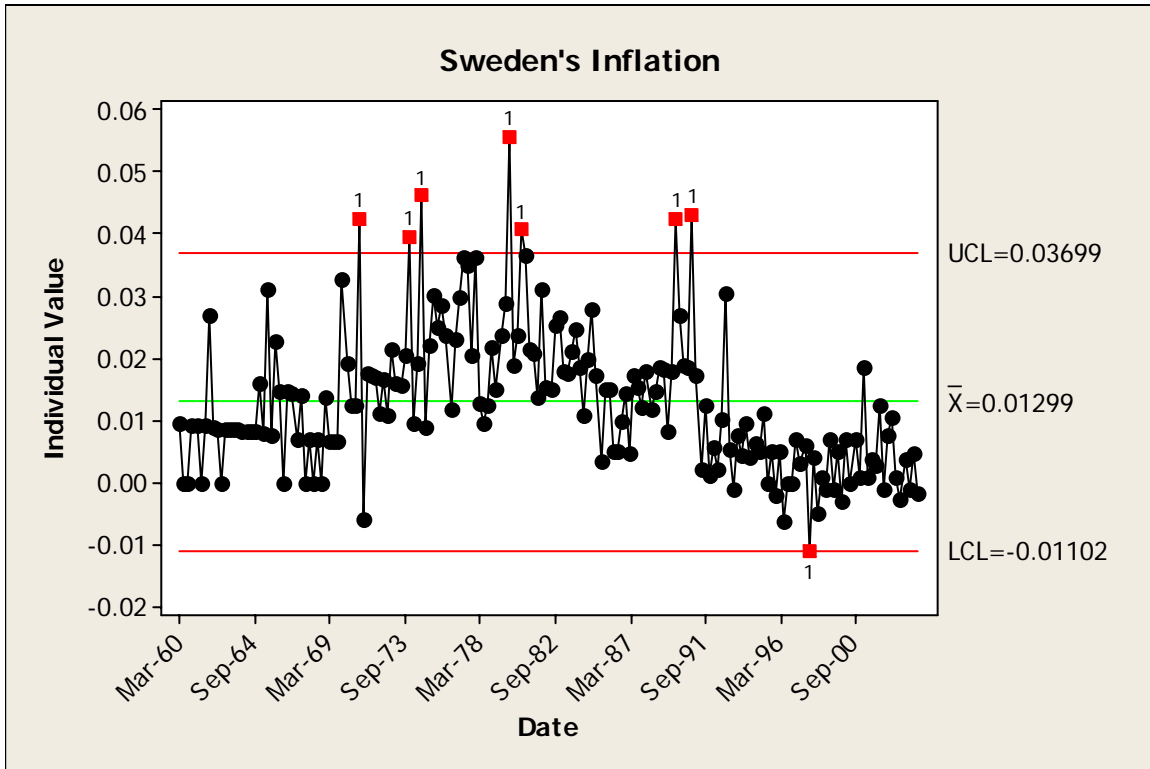


Figure 5: A control chart Sweden



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