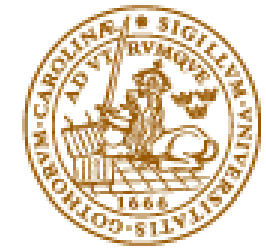


LUND UNIVERSITY

SCHOOL OF ECONOMICS AND MANAGEMENT

Department of Economics

NEKN01

Master Essay

Seminar date: 01 June 2022

Dissecting Inflation:

The effects of inflation volatility on economic growth

Authors:

Joel Cheung

Eric Hansen

Supervisor:

Fredrik NG Andersson

Table of contents

Abstract

Price stability has become an increasingly important target of policy makers. However, the debate on the effects of inflation and economic growth is by no means settled. It is generally agreed that inflation uncertainty harms growth, however, a common challenge in inflation-growth studies lies in the difficulty to separate the effects of inflation rates from inflation volatility. Using inflation rate volatility as a measure of inflation uncertainty, the study aims to untangle the inflation-growth relationship. We hypothesise that the inflation volatility, rather than a given inflation rate itself, has a significant effect on economic growth.

Using a system GMM regression on panel data of 162 countries, ranging from 1990 to 2019, this study finds that it is the volatility of the inflation rate, rather than the inflation rate, itself which affects growth. Further, the results hold when transforming the data into five-year averages, suggesting results are significant for longer time horizons. These results are robust when including relevant growth control variables and when changing the sample to include only non-OECD countries. These results imply that price stability is a sound policy, but the focus should be shifted from targeting a specific rate, to ensuring inflation is kept at a steady and predictable rate.

Keywords: Economic Growth, Inflation, Inflation volatility, Price Stability

1. Introduction

Price stability has become an ever more common pursuit of economic policy. For instance, under treaty article 105, the European Central Bank has stated that price stability remains its primary objective (Bofinger, 1999, p.3). However, the relationship between inflation and economic growth remains uncertain, which calls into question the policy focus on price stability. The negative effects of inflation are commonly attributed to the uncertainty that it creates. However, rapidly developing economies often experience high inflation rates, as domestic demand is boosted by rising income levels. This suggests that a high, but steady, inflation may not necessarily harm growth. Indeed, if inflation was high but predictable, price uncertainty would be eliminated. The purpose of this paper is to determine which element of price stability affects growth, asking whether it is inflation volatility or the inflation rate itself which affects growth.

Understanding whether it is inflation volatility or inflation rate itself is important for policy makers, as much of central banks' efforts are directed towards inflation rate targeting. If it is indeed the predictability of inflation, rather than the rate of inflation that affects economic growth, policymakers need not necessarily target a lower rate of inflation but maintain a steady rate.

Indeed, inflation and economic growth have long been of interest to economic research. While the various nuances of the relationship have been explored, no consensus has been agreed upon regarding the complex subject. Research has attempted to determine if the effect of inflation is positive or negative on growth (Barro, 1995; Khan, Senhadji & Smith, 2006). Building on this, studies then explored if there exists a threshold where the effect of inflation changes from positive to negative (David, Pedro & Paula, 2005; Kremer, Bick & Nautz, 2013). Developing inflation theory further, Eggoh and Khan (2014) focused on exploring the nonlinear effects of inflation on growth.

However, one of the determining factors behind this unclear relationship between inflation and economic growth comes from the underlying problems with data. Studies that focus on a single country, or a group of similar countries in terms of their economic outlook, will typically lack divergent economic experiences, while major international events tend to have a significant influence on the analysis. A common approach for economic researchers to

counter this problem is to run cross-country regressions, which expands the sample to countries with divergent inflationary experiences, which is useful when dissecting the effects of inflation on economic growth (Judson & Orphanides, 1999, p.119). Using this approach, research finds the rate of inflation to have a significant negative effect on economic growth (Barro, 1995; Khan, Senhadji & Smith, 2006).

In a similar vein, research on inflation volatility and economic growth has found the relationship to be significantly negative, when controlling for inflation rate (Al-Marhubi, 1998; Judson & Orphanides, 1999). While cross-country regressions allow for many different economic experiences to be accounted for, results from such research tend to lack sufficient robustness. Levine and Renelt (1992) find that very few variables in cross-country regressions, that are commonly considered significant to growth, are indeed robust when slightly changing the specification of models.

To address problems associated with traditional cross-country regressions, this paper re-examines the relationship between inflation and economic growth, employing a two-step system GMM on data from 162 countries[1] from 1990 to 2019. The sample is further divided into OECD and non-OECD countries. Lastly, the sample is transformed into five-year averages to explore the potential long-term effects of inflation and inflation volatility on economic growth.

This paper theorises that the high volatility of inflation leads to greater uncertainty, which distorts the effective allocation of resources. We hypothesise that the volatility of inflation, rather than a given rate of inflation, has a significant effect on economic growth. Indeed, our results show that it is the volatility of the inflation rate rather than the inflation rate itself which affects growth. These results are robust when including some relevant growth control variables, as well as when changing the sample to include only non-OECD countries.

The remainder of this paper consists of three main parts. First, the theoretical framework of inflation is discussed, along with discussions on some previous economic literature on inflation. Secondly, the data collection and processing are described and the methodology is discussed in greater detail. Lastly, the results of the data analysis are presented and the conclusion and limitations thereof are discussed.

[1] See appendix 10

2. Theoretical Framework

The topic of inflation and its effect on the wider economy has long been at the centre of economic research. Philips (1958) laid the foundation of the so-called Phillips Curve, which suggests that a decrease in inflation leads to an increase in unemployment, similarly, a decrease in unemployment leads to an increase in inflation. This view of the entangled nature of inflation and economic activity would dominate the inflation debate until the hypothesis was weakened by the occurrence of stagflation in the 1970s (Fregert & Jonung, 2018, p.338).

Said stagflation led to a widespread debate between the various economic schools of thought, where the Monetarist view of the Quantity Theory of Money suggests that in the long run, inflation is directly linked to the money supply (Friedman, 1989). Neo-Classical macroeconomic theory suggests that business cycles are affected by real shocks, as opposed to nominal shocks. Therefore, while there may exist short term nominal fluctuations, the long run fluctuations are caused by real shocks (Romer, 2019, p.188). Contrarily, New-Keynesians Economics suggests that prices are sticky, at least in the short run. This suggests that inflation is largely driven by an increase in demand due to increased private or public spending, or due to the drop in the aggregate supply of goods (Keynes, 1936, chap.2; Romer, 2019, pp.262–265)

There exist some contradictory views in which direction the causality flows. According to the Monetarists, inflation is essentially more money chasing the same amount of goods. Holding all else equal, an increase in productivity should lead to more goods and cheaper production. Thus, higher productivity, which increases growth, would have a deflationary effect, rather than an inflationary one (Henderson, 1999). The quantity theory of money is represented in the following equation:

$$(1)\ MV = PQ$$

$$Where\ M = Money\ supply,\ V = Velocity\ of\ money,\ P = Price\ level\ and$$

$$Q = Real\ output\ of\ the\ economy$$

This suggests that if the real output of the economy increases, then price levels must decrease (deflation).

Certain costs are commonly associated with inflation. Even if the inflation rate grows at a given rate, not all prices are instantly adjustable. This leads to a distortion between nominal and real prices, leading to a misallocation of resources. Inflation also distorts the tax system, because income from capital gains is often calculated in nominal terms. Implying that inflation can push consumers to a higher tax bracket, which in turn might lower the incentives for investments and savings, significantly distorting the tax system (Romer, 2019, pp.588–589).

Indexation may be employed to adjust for inflation, whereby contracts are adjusted periodically to an index which tracks inflation rates. However, indexation itself may be inflationary, since an indexed economy inflates more readily than a non-indexed economy. Further, the incentives to combat inflation, for example through monetary policies, are reduced when the effects of inflation are somewhat mitigated by indexation. (Fischer, 1983, p.519)

If the inflation rate is steady and predictable, agents are expected to account for future inflation. Contrarily, if the inflation is volatile, such that there exists an uncertainty of expected future inflation rates, there is a reduction in the information communicated through the price system, as the risk of being locked into contracts which become unfavourable due to deviations of actual versus expected inflation increases. Agents respond by decreasing the duration of contracts to reduce the risk, which increases the frequency of negotiations. This represents an increased frequency in the occurrence and sum of transaction costs which divert resources away from more productive uses. (Al-Marhubi, 1998, p.1318; Choi, Smith & Boyd, 1996, pp.1–3)

Likewise, investment by nature also involves a “lock-in” period where initial capital can not be withdrawn. Increased inflation uncertainty reduces the attractiveness of investments in a given country, which is a key driver of growth (Al-Marhubi, 1998, p.1318; Barro, 1995, pp.18–19). More generally, inflation uncertainty reduces the attractiveness of a currency, which encourages capital flight. This pulls money away from being spent in the local economy, be that on investments or consumption (Al-Marhubi, 1998, p.1318).

Inflation uncertainty erodes the allocative function of capital markets. The attractiveness of nominal assets, such as stocks, is eroded, which shifts investments towards real assets, such as gold and real estate. This means money is being diverted towards capital

accumulation rather than investments. This again represents a diversion of capital towards potentially less productive uses. (Al-Marhubi, 1998, p.1318; Choi, Smith & Boyd, 1996, pp.1–3)

Barro (1995) estimates the relationship between inflation rates and economic growth using cross-country estimations of 100 countries from 1960-1990. While the estimations suggest a negative coefficient for inflation, when controlling for plausible control variables, the paper emphasises that statistically significant results only emerge when high inflation countries are included in the sample.

Looking beyond inflation rates, Al-Marhubi (1998) attempts to investigate the effects of inflation volatility on GDP per Capita, employing a cross-country analysis of 78 countries between the period 1965-1985. The measure for inflation volatility is the standard deviation of the residuals for each country. The results show that high inflation volatility is associated with a negative effect on the growth of GDP.

Khan (2006) dives deeper into the relationship, looking at the mechanisms through which the negative effects are transmitted, focusing on financial markets. Using a cross-country approach with data from 168 countries from 1960-1999, this paper finds the relationship to be non-linear with threshold effects, where the effect of inflation turns negative at a 3-6% annual inflation rate.

In response to the vast range of cross-country studies, Levine (1992) analyses the robustness of results from such studies, questioning if it is reasonable to group all countries into the same regression, arguing that not all countries are easily comparable. When slightly altering the specifications of previous growth regressions, Levine (1992) finds that many of the indicators used are not robustly correlated with growth. This implies that there is not a reliable, independent, statistical relationship between many of the macroeconomic indicators and growth. Judson and Orphanides (1999) build on Levine's (1992) insights, by fully utilising both the time and panel nature of the cross country data and employing an intra-year rather than an inter-year measure of volatility. They find that both inflation and inflation volatility have a significant negative impact on growth.

When running regressions of panel data on growth, Caseli et al (1996) show that endogeneity of explanatory variables has a strong role in driving results in growth studies,

potentially undermining the validity of previous research. To overcome this, Eggod and Khan (2014) use the Generalised Method of Moments (GMM) techniques to reexamine the non-linear relationship between inflation and economic growth. The results validate the previous research on the non-linear effects of inflation on economic growth.

3. Data

3.1 Data Description

All data is gathered from The World Bank, except for investments, which are acquired from Penn World Table. The dataset consists of data for 162 countries[2] and territories spanning 30 years from 1990 to 2019. The full sample includes a total of 3915 observations. All variables are in logarithmic form, except for those variables which may take negative values.

The choice of the time period is two-fold. Firstly, due to the availability of data. Secondly, the vastly different economic landscape that existed before the 1990s. Before the 1970s, much of the world's countries used the gold standard or derivatives thereof. After the termination of the Bretton Woods system in the early 1970s, many countries experienced a period of economic instability as they adapted to the new economic reality.

GDP is the dependent variable of the estimations, which describes GDP per Capita in 2022 US Dollars and is used to illustrate the economic growth of a country. GDP is divided by the midyear population. The one period lagged GDP is further included as an explanatory variable to account for the dynamic process of the dependent variable.

Inflation measures the annual percentage change in consumer prices. This measure is included to capture the role of price changes in the economy. Inflation is generally found to have a negative coefficient concerning economic growth. As inflation may take a negative value, the variable is not in logarithmic form.

Inflation Volatility measures the uncertainty of future prices. It is calculated as the standard deviation of the past five observations of inflation, giving the following formula:

$$(2)\ \sigma_t = \sqrt{\frac{1}{N}\sum(x_i - \overline{x})^2} \quad where\ \sigma_t = volatility,\ \ N = 5$$

[2] Se Appendix 10

By using this measure of volatility, we capture some of the lagged effects of volatility, while outlier's lingering effects throughout the sample period are minimised. Different choices of the time variable N are possible, depending on the assumptions made of the lingering effects of inflation. However, considering the length of the business cycle, which is generally considered to be 2-10 years, five years is the conservative decision. Volatility may also be measured by taking the individual deviations from the mean of the full sample period. However, this causes short periods of high inflation to have a strong effect on the sample mean, amplifying the measured volatility throughout the sample period. Inflation volatility is constructed to illustrate the uncertainty of inflation, which is expected to harm economic growth.

In addition to the variables of interest, we include control variables to investigate the robustness of the results. *Investments* are calculated by subtracting "Real consumption of households and government" from "Real domestic absorption" (real consumption plus investment) in the Penn World Table database. The variable is reported in million 2017 US Dollars. Investments are generally considered to be robustly, and positively correlated with GDP growth (Levine & Renelt, 1992).

Following Al-Marhubi (1998), we include *Population growth* as a control variable which is calculated as the annual percentage growth in population. Population growth is expected to harm GDP per capita, since, all else equal, a larger population shares the same amount of GDP. Because population growth may be negative, the variable is not in logarithmic form.

Government Expenditure describes general government final consumption expenditure in 2022 US Dollars. The effect on Government Expenditure is generally found to diminish economic growth (Landau, 1983; Levine & Renelt, 1992).

Trade describes the sum of exports and imports of goods and services as a share of GDP. The theoretical ties between trade and economic growth are considered to run through improved resource allocation, which suggests a positive effect on economic growth (Al-Marhubi, 1998; Levine & Renelt, 1992).

To further control the robustness of the results for a longer time horizon, the data is modified to five-year averages to consider long run effects and to account for business cycles.

Robustness is further extended by grouping the samples into OECD and non-OECD countries. The countries classified as OECD are those countries which were OECD members as of 2021.

Table 1: Variables and expected signs

Variables	Expected sign (short term)	Expected sign (long term)
Explanatory		
GDP (lagged)	+	+
Inflation	-	No effect
Inflation volatility	-	No effect
Control variables		
Investments	+	+
Population Growth	-	-
Government expenditure	-	-
Trade	+	+

3.2 Descriptive Statistics

Table 2: Descriptive Statistics after transformations

Variable	Obs	Mean	Std. Dev.	Min	Max
GDP	4728	11.027	2.102	5.397	16.853
Inflation	4728	28.092	399.108	-18.109	23773.131
Inflation volatility	4728	1.733	1.418	-1.569	9.952
Investments	4727	9.422	2.261	3.349	16.028
Population Growth	4723	1.473	1.436	-6.766	17.512
Government Expenditure	4169	2.678	.409	-.093	4.334
Trade	4258	4.285	.606	-3.863	6.093

Inflation within our data set has a mean of 28% and a high degree of variability between observations as shown by the standard deviation of nearly 400. Bhutan in 2004 and the Democratic Republic of the Congo (DRC) in 1994 had the lowest and highest rates of inflation respectively. Similarly, inflation volatility showed high variability between observations with the highest achieved by the DRC in 1998 and the lowest by the Netherlands in 1998.

Median inflation and inflation volatility levels, shown in appendix 6 and 7, show that OECD countries generally had milder experiences while both groups generally experienced higher levels of both measures in the 90s than after the turn of the millennium. Appendix 8 shows that inflation rates are clustered between 0-5%. OECD countries had a much denser distribution of inflation rates which were generally slightly lower than their non-OECD counterparts. Appendix 9 shows that volatility levels are clustered around 2-3, OECD countries again had a denser distribution with generally lower volatility levels. This shows that there is a degree of homogeneity amongst OECD members' inflation and inflation volatility experiences, this is logical given that to become an OECD member countries must fulfil certain criteria.

4. Methodology

4.1 Model Selection

The generalised method of moments (GMM) estimation is employed, which offers some desirable features well suited to the panel nature of our data, when compared to an ordinary least squares (OLS) or a standard instrumental variables (IV) study. GMM is suited to situations with many groups and few time periods, where the dependent variable is dynamic, in that it depends on its lag. The GMM allows for heteroscedastic and not strictly exogenous independent variables, where auto-correlation may exist within groups. (Roodman, 2009, p.86)

In this study, it is difficult to assume strict exogeneity of the explanatory variables. For example correlation between inflation rates and the error term may exist, meaning the higher the inflation rate, the greater the error term. Variables found to be significant from previous growth studies, for example, investments (Barro, 1995), can be controlled for. However, countries likely differ in observable ways which are overlooked, since it is impossible to account for all observable characteristics. GMM controls for the endogeneity of regressors and omitted variable bias (Roodman, 2009, p.104).

Even if all observable differences between countries could be controlled for, the macro nature of the study inevitably means countries are also likely to vary in unobservable ways. Therefore, it is reasonable to assume that one country's GDP may react differently to changes in explanatory variables than that of another country. In the presence of such heteroscedasticity, the GMM estimator, by utilising a weighting matrix, is more efficient than an IV estimator (Baum, Schaffer & Stillman, 2003, p.14). Therefore this paper employs the GMM model.

There exist different variations of the GMM. The original version of the GMM is a difference GMM. Through differencing, the difference GMM removes time invariant fixed effects. However, the problem of endogeneity remains as the correlation between the lagged dependent variable and the lagged error term remains.

A random walk model where the dependent variable is persistent is assumed. This will lead to biased results when applying a differenced GMM, due to the use of weak instruments (Blundell & Bond, 1998, p.116). To overcome this we follow previous studies,[3] applying a system GMM which involves more moment conditions, providing gains in precision and reducing small sample bias (Arellano & Bond, 1991, p.291). Therefore the paper employs a system GMM, instead of a differenced GMM.

4.2 Validity checks

To ensure the validity of the GMM estimates, the number of groups, in our case countries, needs to be sufficiently more than the number of instruments. Further, by using GMM, our model is vulnerable to over or under-identification issues, which is when the number of instruments is different from the number of regressors. To check for this the Hansen test statistics have been considered for all GMM outputs. The Hansen test statistic tests the null hypothesis that there are over-identification issues, therefore significant p-values, in our case at a 10% significance level, signify identification issues.

The cumulative nature of GDP means that an economic shock in a period may affect both the error term within that period but also have lingering effects, changing error terms in future periods also. This introduces the risk of auto-correlation, whereby error terms between periods are correlated, that is: $Cov(\varepsilon_t, \varepsilon_{t-1}) \neq 0$. To check for this, the AR(2) validity check tests the null hypothesis that error terms are serially correlated.

4.3 Empirical operationalisation

Following Bond et al's (2001, p.6) suggestion, an initial ordinary least squares (OLS) regression, fixed effects and one step differenced GMM regressions are performed. The outputs in appendix 1 and 3 show lower lagged dependent variable coefficients in the 1 stage GMM compared to the output of the fixed effect. This suggests that the differenced GMM is downward bias due to weak instrumentation and that system GMM should be employed (Blundell & Bond, 1998, p.117).

[3] See for example Eggoh & Khan, 2014; Kremer, Bick & Nautz, 2013

The correlation matrix (Appendix 2) shows correlation between inflation and inflation volatility, confirming previous findings (Al-Marhubi, 1998, p.1320) that their individual effects can not be found with typical OLS regressions. The variance inflation factor measurement (Appendix 5) does not show any worryingly high levels of multicollinearity. Baum et al (2003, p.15) suggest that if error terms are homoscedastic, an IV estimation would be preferable to GMM, we perform their recommended check (Appendix 4) finding the errors to be heteroscedastic.

Year/period dummies are included to capture effects that affect all countries in a given year/period. Further, volatility, investments, population growth and year/time period dummies are used to create instrumental variables for the lagged dependent variable. While they may not all be strictly exogenous, they can at least reasonably be assumed to satisfy the assumption of predetermination. We then calculate long-run coefficients from all variables with significant short run coefficients.

$$(3)\ \beta_L = \beta_S \ \div (1-\phi)$$

$$Where\ \beta_L = long\ run\ coefficient,$$

$$\beta_S = short\ run\ coefficient,$$

$$\phi = lagged\ dependent\ variable$$

$$(4)\ Our\ model: \Delta lnY_{it} = \phi lnY_{it-1} + \beta_i \Delta X_{it} + \gamma_i \Delta W_{it} + \Delta\varepsilon_{it}$$

$$Where\ Y_{it} = GDP\ per\ capita$$

$$X_{it} = Explanatory\ variables$$

$$W_{it} = Control\ variables$$

Due to the unbalanced nature of our panel data, we minimise data loss following Kremer's (2013, p.17) approach of taking orthogonal deviations, that is the differencing between the contemporaneous observation and the average of all future observations (Arellano & Bover, 1995, p.31). Our model is shown above in equation 4, where logged GDP is the dependent variable, lagged logged GDP is a right-hand side variable, inflation and inflation volatility are the explanatory variables, and relevant growth control variables (See Table 1).

5. Results

5.1 Yearly Results

Regression outputs in table 3 show regressions for the full sample, as well as when filtering for OECD and non-OECD countries, while table 4 shows long-run coefficients for the significant coefficients from table 3. Lagged GDP per capita unsurprisingly has a significant coefficient for all regression outputs. All results are interpreted for their effects on average, holding all else equal. When looking at the full sample, only volatility and investments are significant. The AR(2) and Hansen statistics show P-values greater than 0.1, meaning we can reject the null for both cases.

The coefficient for inflation volatility is -0.030. This implies that a one percentage change in inflation volatility is associated with a 0.03% decrease in economic growth in the short run at the 1% significance level. Hence, inflation volatility and GDP exhibit an inelastic relationship. The corresponding long run coefficient, shown in table 4, for volatility is substantially larger, at -0.295, implying that a one percentage change in inflation is associated with a 0.295% decrease in economic growth in the long run at a 1% significance level.

The coefficient for investments is 0.024 at a 5% significance level. This means that a one percentage change in investments is associated with a 0.024% increase in economic growth in the short run at the 5% significance level. The long-run coefficient is 0.236, implying that a one percentage change in investments is associated with a 0.236% increase in economic growth at a 1% significant level.

For non-OECD countries, shown in column 2, the coefficient for inflation volatility is now slightly lower at -0.035. This implies that a one percentage change in inflation volatility is associated with a 0.035% decrease in economic growth in the short-run at the 10% significance level. Hence, inflation volatility and GDP still exhibit an inelastic relationship. The corresponding long run coefficient for volatility is substantially lower, at -0.263, implying that a one percentage change in inflation is associated with a 0.263% decrease in economic growth in the long run at a 10% significance level.

The coefficient for trade is 0.068 at a 10% significance level. This means that, in the short term, a one percentage change in investments is associated with a 0.068% increase in

economic growth at the 10% significance level. The long-run coefficient is significantly larger at 0.516, implying that a one percentage change in trade is associated with a 0.516% increase in long term economic growth. The long-run coefficient is, however, not significant at a 10% significance level

When looking at non-OECD countries and the full sample, we can reject the null given the p-values for the Hansen and AR(2) statistics. For OECD countries, shown in column 3, the output is considered invalid as it suffers from instrument proliferation, that is the number of instruments is greater than the number of countries. Furthermore, we are unable to reject the null for the AR(2) statistic.

Table 3: Regression output for yearly results

VARIABLES	(1) Full Sample	(2) non-OECD	(3) OECD
GDP per capita (lagged)	0.898***	0.868***	0.910***
	(0.031)	(0.069)	(0.065)
Inflation	-0.000	-0.000	0.007
	(0.000)	(0.000)	(0.019)
Volatility	-0.030**	-0.035*	-0.056
	(0.013)	(0.019)	(0.074)
Investments	0.024**	0.011	-0.001
	(0.010)	(0.015)	(0.005)
Population Growth	-0.007	-0.015	-0.003
	(0.011)	(0.020)	(0.010)
Government Expenditure	0.010	-0.000	0.002
	(0.010)	(0.014)	(0.009)
Trade	0.033	0.068*	-0.003
	(0.024)	(0.039)	(0.036)
Constant	0.432**	0.689	0.859
	(0.178)	(0.423)	(0.713)
Observations	3,915	2,905	1,010
Countries	162	121	41
AR(2)	0.152	0.293	0.00679
Hansen	0.290	0.355	0.827
Instruments	62	62	62

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4: Long run coefficients for significant coefficients from yearly valid regression output

		Full sample	non-OECD	OECD
Yearly	Investments	0.236*** (0.0485)		
	Volatility	-0.295*** (0.105)	-0.263* (0.133)	
	Trade		0.516 (0.274)	

5.2 Five-year average results

To control for business cycles, table 5 shows regression outputs taken from five-year averages of all the variables, while table 6 shows long-run coefficients for significant coefficients from table 5. As in the yearly case, lagged GDP has, as expected, a significant effect on GDP.

Column 1 shows regression output for the full sample, where both volatility and investments are significant. Furthermore, the AR(2) and Hansen statistics show P-values greater than 0.1, meaning the null can be rejected in both cases. Inflation volatility has a coefficient of -0.218. This entails that, in the short term, a one percentage change in inflation volatility is associated with a 0.218% decrease in economic growth at a 5% significance level. The associated long run coefficient for volatility, shown in table 6, is -0.489, implying that a one percentage change in inflation volatility is associated with a 0.489% decrease in long term economic growth at a 1% significance level.

The coefficient for investments is 0.129. This implies that, in the short term, a one percentage change in investments is associated with a 0.129% increase in economic growth at a 1% significance level. The corresponding long-run coefficient is 0.288 which implies that a one percentage change in investments is associated with a 0.288% increase in long run economic growth at a 1% significance level.

Column 2 shows the regression output for non-OECD countries. Inflation volatility has a coefficient of -0.229. This implies that in the short term, a one percentage change in inflation volatility is associated with a 0.229% decrease in economic growth at a 5% significance level. The corresponding long run coefficient for volatility is -0.792, this means that a one percentage change in inflation volatility is associated with a 0.792% decrease in long term economic growth at a 1% significance level.

The coefficient for investments is 0.047. This implies that a one percentage change in investments is associated with a 0.047% increase in economic growth at a 1% significance level, in the short term. The corresponding long-run coefficient is 0.163 which implies that a one percentage change in investments is associated with a 0.163% change in long run economic growth at a 1% significance level. Furthermore, we can reject the null for both the AR(2) and Hansen tests.

Column 3 shows the regression output for OECD countries. There are no significant coefficients and the Hansen statistic is less than 0.1, meaning we are unable to reject the null that we have instrument identification issues. The output is thus considered invalid and not interpreted.

Table 5: Five-year average

VARIABLES	(1) Full Sample	(2) non-OECD	(3) OECD
GDP per capita	0.553***	0.711***	0.794***
	(0.166)	(0.134)	(0.336)
Inflation	-0.000	0.001	0.003
	(0.001)	(0.001)	(0.037)
Volatility	-0.218**	-0.229***	-0.095
	(0.099)	(0.063)	(0.221)
Investments	0.129***	0.047**	0.000
	(0.044)	(0.021)	(0.015)
Population Growth	-0.106	-0.030	-0.021
	(0.116)	(0.054)	(0.039)
Government Expenditure	-1.249	-0.305	-0.005
	(2.101)	(1.040)	(0.471)
Trade	0.780	0.336	0.006
	(0.631)	(0.406)	(0.161)
Constant	3.638	1.489	2.348
	(2.829)	(1.812)	(3.482)
Observations	673	506	167
Countries	159	120	39
AR(2)	0.726	0.528	0.987
Hansen	0.286	0.410	0.0372
Instruments	15	15	15

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 6: Long run coefficients for significant coefficients from five-year averages valid regression output

		Full sample	non-OECD	OECD
Five-year averages	Volatility	-0.489*** (0.147)	-0.792* (0.308)	
	Investments	0.288*** (0.0687)	0.163*** (0.0438)	

6. Discussion

The estimated negative and significant inflation volatility coefficient supports the paper's hypothesis that inflation uncertainty is associated with a negative effect on economic growth. Furthermore, the results are consistent in both the short and long term. The coefficient for volatility is estimated as stronger (more negative) when filtering for non-OECD countries compared to the full sample. OECD countries generally have not experienced major inflation spikes within the observation period. Therefore when they are taken out of the sample it is expected that the effect on the countries left in the sample (non-OECD) is stronger.

The significant negative volatility coefficients paired with the insignificant inflation coefficients for all valid outputs re-enforces the hypothesis that the uncertainty of inflation rates affects growth, rather than the inflation rate itself. As discussed, if the rate of inflation is high but predictable, an agent would account for the future inflation (Al-Marhubi, 1998; Choi, Smith & Boyd, 1996). Inflation volatility exhibits stronger (larger absolute value) longer-run coefficients, which suggests that their lingering effects are stronger than their next year effects. This finding has implications for central banks, suggesting that shifting focus from targeting low inflation rates to inflation stability may be beneficial. That is, for a given inflation rate, central bankers may be better off working to ensure the inflation rate stays constant than attempting to decrease it.

When looking at the yearly regression outputs, the positive coefficients of investments largely confirm findings from previous literature (Levine & Renelt, 1992) on the important role of investments in growth models. The consistency with previous findings adds validity to our model. The robustness of this interpretation is strengthened by the inclusion of common growth variables, and the result holds when both considering the full sample and only non-OECD countries.

The results from the estimates of the five-year averages suggest that inflation volatility has a significant negative effect on economic growth when controlling for business cycles. These results give further credibility to the hypothesis that the uncertainty of the inflation, rather than a given rate of inflation, harms economic growth. Furthermore, the

results are again robust when controlling for investments and when considering only non-OECD countries.

The significance of the five-year average long-run coefficients suggests that the negative effect of volatility becomes stronger for longer time horizons. Furthermore, the coefficient for volatility becomes more negative when considering only non-OECD countries. This is to be expected, like in the yearly regressions, since OECD countries have experienced few episodes of notable inflation over the past three decades. However, the invalid results for the OECD only sample prohibit further analysis of OECD countries. The significant results give support to the New-Keynesian view of the relevance of nominal changes, at least in the short term to medium term. Although longer time horizons are taken into account, they can hardly be considered long term in a macroeconomic sense. Therefore, these results do not undermine the neoclassical view that fluctuations in the economy are only affected by "real" shocks.

When comparing the results of inflation volatility for the yearly and five-year average regressions a consistent pattern emerges. When the variable is significantly negative, its long run coefficient is also negative but stronger. This is consistent with the theory that prices are sticky, and contracts take time to adjust to inflation (Romer, 2019, pp.588–589). Therefore, while some effects of increased inflation uncertainty can be felt immediately, it takes time for the economy to fully adjust to increased inflation uncertainty. Knowing that the effects are stronger in the long-run, can help policymakers' decisions about the size and frequency of fiscal policies which affect inflation.

Our results hold all other factors constant and countries within our sample have different inflation experiences. While reducing inflation volatility will increase growth on average, this effect is not guaranteed in a specific country. However, the key policy implication from these results, that high inflation uncertainty carries a negative effect on economic growth, remains.

7. Conclusions

This paper has examined the relationship between inflation, inflation volatility and economic growth asking whether it is inflation volatility or inflation rates themselves which affect growth. We find that inflation volatility has a significant negative effect on economic growth and that the estimated coefficient becomes more negative when sampling only non-OECD countries. Since OECD countries generally have experienced fewer periods of high inflation volatility, this is to be expected. Furthermore, the results were robust controlling for some additional variables.

Inflation volatility increases the uncertainty of future inflation rates. This undermines the price mechanism through which market information is transmitted to agents which ensures the efficient allocation of resources. Therefore increased inflation volatility harms growth. The lack of statistical significance for inflation suggests that the rate of inflation itself doesn't affect economic growth, but rather the uncertainty of future inflation. The significance of the five-year averages and stronger long run coefficient suggests that the effects of increased uncertainty are not necessarily felt immediately, rather that it takes some time for the economy to react to the higher uncertainty.

The relevance for policymakers is twofold. Firstly, focusing on price stability is a sound policy, but the focus should be shifted from achieving a specified inflation rate to ensuring inflation is kept at a steady and predictable rate. Secondly, the rewards from targeting stable inflation rates will take time to become apparent, which could help policymakers in deciding when to implement fiscal policies which may affect inflation rates.

Our results are largely in line with the existing theory about inflation, showing that inflation uncertainty hampers economic growth. Further research can explore the mechanisms through which inflation might affect growth such as investments and financial markets, to examine their respective importances. The model can be extended to include other sample groups and sample periods, to further explore how different countries are affected by inflation.[4] We leave such endeavours for future research.

[4] Judson (1999), for example, divides the sample into, amongst others, non-oil producing countries.

References

Al-Marhubi, F. (1998). Cross-Country Evidence on the Link between Inflation Volatility and Growth, *Applied Economics*, vol. 30, no. 10, pp.1317–1326.

Arellano, M. & Bond, S. (1991). Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations, *The Review of Economic Studies*, vol. 58, no. 2, pp.277–297.

Arellano, M. & Bover, O. (1995). Another Look at the Instrumental Variable Estimation of Error-Components Models, *Journal of Econometrics*, vol. 68, no. 1, pp.29–51.

Barro, R. J. (1995). Inflation and Economic Growth.

Baum, C. F., Schaffer, M. E. & Stillman, S. (2003). Instrumental Variables and GMM: Estimation and Testing, *The Stata Journal: Promoting communications on statistics and Stata*, vol. 3, no. 1, pp.1–31.

Blundell, R. & Bond, S. (1998). Initial Conditions and Moment Restrictions in Dynamic Panel Data Models, *Journal of Econometrics*, vol. 87, no. 1, pp.115–143.

Blundell, R., Bond, S. & Windmeijer, F. (2001). Estimation in Dynamic Panel Data Models: Improving on the Performance of the Standard GMM Estimator, in B. H. Baltagi, T. B. Fomby, & R. Carter Hill (eds), *Nonstationary Panels, Panel Cointegration, and Dynamic Panels*, Vol. 15, Emerald Group Publishing Limited, pp.53–91.

Bofinger, P. (1999). The Monetary Policy of the ECB Under Treaty Article 105, *Economic affairs series*, vol. 04.

Caselli, F., Esquivel, G. & Lefort, F. (1996). Reopening the Convergence Debate: A New Look at Cross-Country Growth Empirics, *Journal of Economic Growth*, vol. 1, no. 3, pp.363–389.

Choi, S., Smith, B. D. & Boyd, J. H. (1996). Inflation, Financial Markets, and Capital Formation, *Federal Reserve Bank of St.Louis*, p.27.

David, D., Pedro, G.-P. & Paula, H. (2005). Threshold Effects in the Relationship between Inflation and Growth: A New Panel-Data Approach, *MPRA Paper*.

Eggoh, J. C. & Khan, M. (2014). On the Nonlinear Relationship between Inflation and Economic Growth, *Research in Economics*, vol. 68, no. 2, pp.133–143.

Fischer, S. (1983). INDEXING AND INFLATION, *Journal of Monetary Economics*, vol. 12, pp.519–541.

Fregert, K. & Jonung, L. (2018). Makroekonomi teori, politik och institutioner, Fifth Edition.,

Studentlitteratur.

Friedman, M. (1989). Quantity Theory of Money, London: Palgrave Macmillan.

Henderson, D. R. (1999). Does Growth Cause Inflation?, *CATO institute*, Available Online: https://www.cato.org/policy-report/november/december-1999/does-growth-cause-inflation# [Accessed 18 May 2022].

Judson, R. & Orphanides, A. (1999). Inflation, Volatility and Growth, *International Finance*, vol. 2, no. 1, pp.117–138.

Keynes, J. M. (1936). The General Theory of Employment, Interest and Money: The Economic Consequences of the Peace, Ware: The quarterly journal of economics.

Khan, M. S., Senhadji, A. S. & Smith, B. D. (2006). Inflation and Financial Depth, *Macroeconomic Dynamics*, vol. 10, no. 2, pp.165–182.

Kremer, S., Bick, A. & Nautz, D. (2013). Inflation and Growth: New Evidence from a Dynamic Panel Threshold Analysis, *Empirical Economics*, vol. 44, no. 2, pp.861–878.

Landau, D. (1983). Government Expenditure and Economic Growth: A Cross-Country Study, *Southern Economic Journal*, vol. 49, no. 3, p.783.

Levine, R. & Renelt, D. (1992). A Sensitivity Analysis of Cross-Country Growth Regressions, *The American Economic Review*, vol. 82, no. 4, pp.942–963.

Phillips, A. W. (1958). The Relation between Unemployment and the Rate of Change of Money Wage Rates in the United Kingdom, 1861-1957, *Economica*, p.18.

Romer, D. (2019). Advanced Macroeconomics, Fifth Edition., Dubuque: McGraw-Hill Education.

Roodman, D. (2009). How to Do Xtabond2: An Introduction to Difference and System GMM in Stata, *The Stata Journal*, vol. 9, no. 1, pp.86–136.

Appendix

Appendix 1: Yearly outputs for OLS, fixed effects and 1 stage differenced GMM

VARIABLES	(1) OLS	(2) Fixed effects	(3) 1 stage difference GMM
GDP per capita (lagged)	0.990***	0.872***	0.805***
	(0.002)	(0.011)	(0.064)
Inflation	-0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)
Volatility	0.005*	-0.009**	-0.101***
	(0.003)	(0.004)	(0.022)
Investments	0.003***	0.074***	0.099
	(0.001)	(0.009)	(0.074)
Population Growth	-0.004**	-0.009***	0.091*
	(0.002)	(0.003)	(0.053)
Government Expenditure	-0.001*	-0.003**	-0.002
	(0.000)	(0.001)	(0.011)
Trade	0.015***	0.032	0.119
	(0.004)	(0.022)	(0.105)
Constant	0.046*	0.335***	
	(0.024)	(0.098)	
Observations	3,915	3,915	3,753
Countries	.	162	162
R-squared	0.993	0.947	
AR(1)	.	.	4.14e-05
AR(2)	.	.	0.0260
Hansen	.	.	2.33e-09
Sargan	.	.	0
Instruments	.	.	28

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Appendix 2: Pairwise correlations of explanatory and control variables

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) ln_gdppc	1.000							
(2) L.ln_gdppc	0.997	1.000						
(3) L.inflation	-0.067	-0.067	1.000					
(4) L.ln_volatility	-0.502	-0.508	0.224	1.000				
(5) L.ln_investments	0.448	0.447	-0.011	-0.223	1.000			
(6) L.popgrowth	-0.191	-0.188	0.035	0.084	-0.114	1.000		
(7) L.govexp	0.198	0.199	-0.034	-0.070	0.028	-0.220	1.000	
(8) L.ln_trade	0.242	0.238	-0.038	-0.166	-0.023	-0.114	0.214	1.000

Appendix 3: Five-year average outputs for OLS, fixed effects and 1 stage differenced GMM

VARIABLES	(1) OLS	(2) Fixed Effects	(3) 1 Stage difference GMM
GDP per capita (lagged)	0.939***	0.446***	0.246
	(0.011)	(0.071)	(0.154)
Inflation	-0.000	0.000	0.002
	(0.000)	(0.000)	(0.002)
Volatility	-0.051**	-0.069***	0.081
	(0.020)	(0.017)	(0.119)
Investments	0.029***	0.472***	1.136***
	(0.005)	(0.046)	(0.218)
Population Growth	-0.006	-0.026**	-0.350
	(0.009)	(0.010)	(0.454)
Government Expenditure	-0.030	-0.089	-3.681**
	(0.034)	(0.069)	(1.780)
Trade	0.099***	0.069*	-0.190
	(0.024)	(0.041)	(1.401)
Constant	0.261	0.304	
	(0.161)	(0.267)	
Observations	677	677	517
Countries	.	160	152
R-squared	0.960	0.821	
AR(1)	.	.	0.500
AR(2)	.	.	0.321
Hansen	.	.	0.218
Sargan	.	.	0.746
Instruments	.	.	10

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

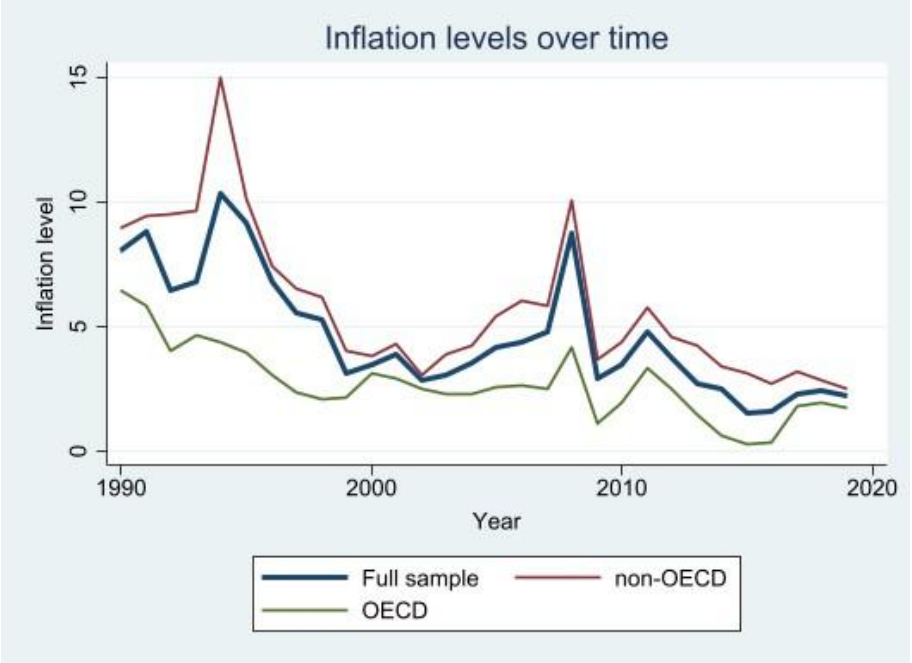
Appendix 4: Testing for heteroscedasticity

OLS heteroscedasticity test(s) using levels of IVs only
Ho: Disturbance is homoscedastic
White/Koenker nR2 test statistic: 152.412
Chi-sq(7) P-value = 0.0000

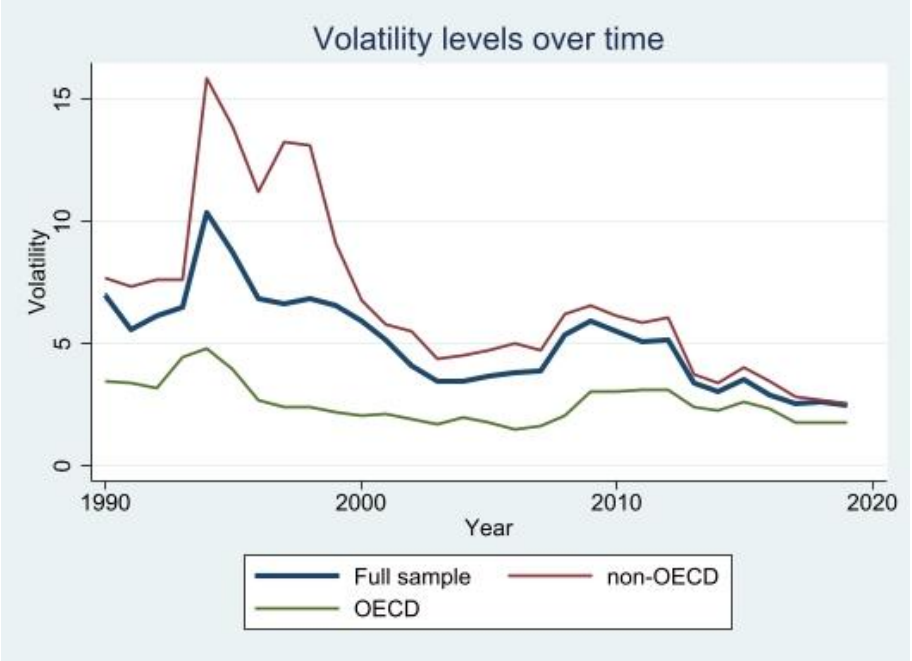
Appendix 5: VIF statistics

	VIF	1/VIF
GDP per capita (lagged)	1.720	0.581
Volatility	1.410	0.709
Investments	1.250	0.802
Trade	1.120	0.892
Government expenditure	1.110	0.898
Population growth	1.080	0.928
Inflation	1.040	0.960
Mean VIF	1.250	

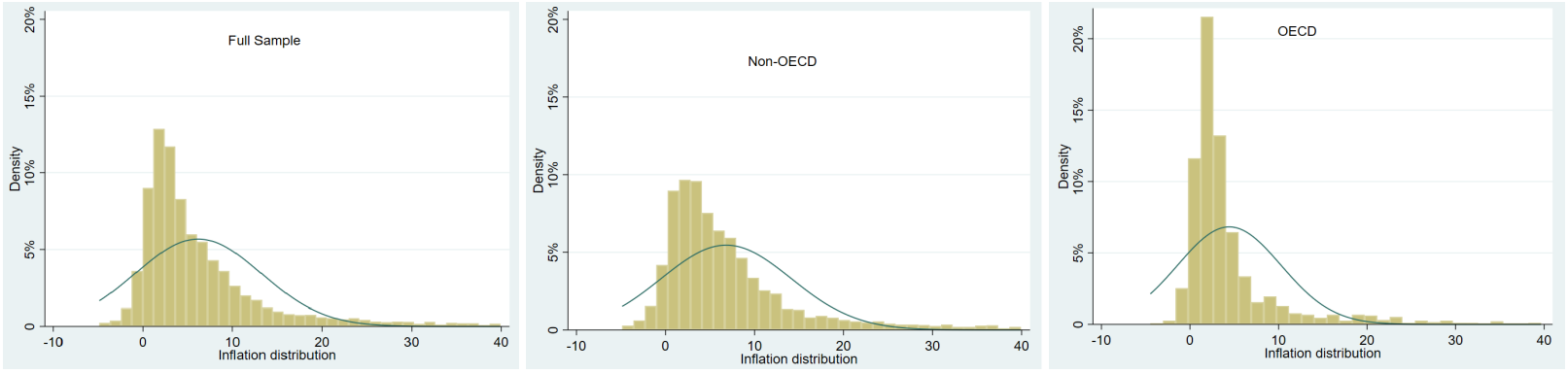
Appendix 6: Median inflation rates development over time



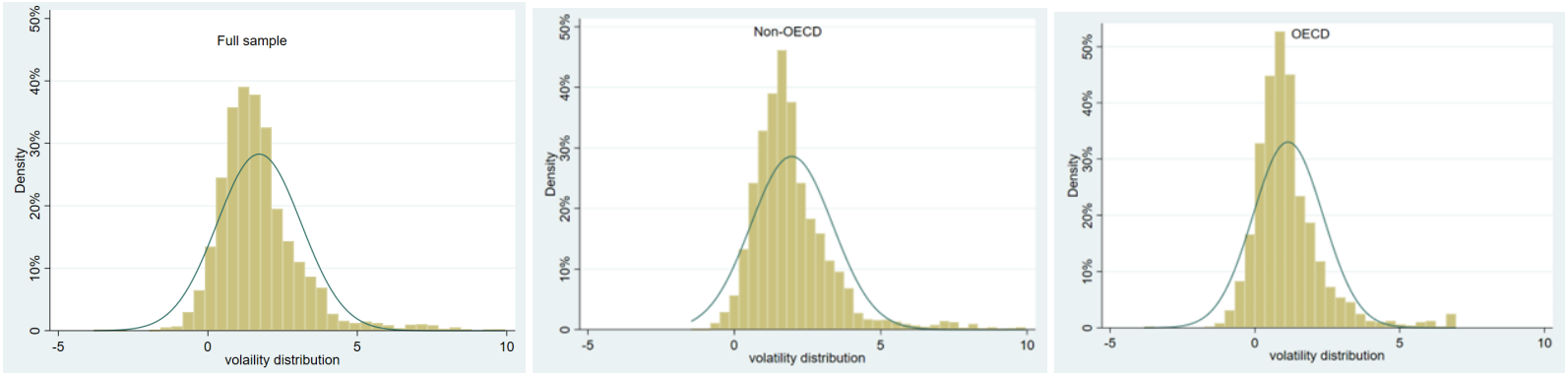
Appendix 7: Volatility levels development over time



Appendix 8: Distribution of inflation levels by group, cut-off at 40%



Appendix 9: Distribution of inflation volatility levels by group



Appendix 10: Countries included in the sample

OECD		**Non-OECD**				
Australia	New Zealand	Angola	Cambodia	Hong Kong	Mauritania	Sao Tome & Principe
Austria	Poland	Albania	Congo, Dem. Rep.	Honduras	Mauritius	Suriname
Belgium	Portugal	Algeria	Congo, Republic	Indonesia	Malawi	Seychelles
Canada	Slovakia	Argentina	Comoros	India	Malaysia	St. Kitts and Nevis
Chile	Slovenia	Armenia	Cape Verde	Iran	Namibia	St. Vincent & the
Colombia	South Korea	Antigua and Barbuda	Croatia	Iraq	Niger	St. Lucia
Costa Rica	Spain	Azerbaijan	Chad	Jamaica	Nigeria	Sri Lanka
Cyprus	Sweden	Burundi	Djibouti	Jordan	Nicaragua	Grenadines
Czech Republic	Switzerland	Benin	Dominica	Kazakhstan	Nepal	Syria
Denmark	Turkey	Burkina Faso	Dominican Republic	Kenya	Oman	Togo
Estonia	United Kingdom	Bangladesh	Ecuador	Kyrgyzstan	Pakistan	Thailand
Finland	United States	Bulgaria	Egypt	Kuwait	Panama	Tajikistan
France		Bahrain	Ethiopia	Laos	Peru	Turkmenistan
Germany		Bahamas	Eswatini	Lebanon	Philippines	Trinidad and Tobago
Greece		Bosnia & Herzegovina	Equatorial Guinea	Liberia	Paraguay	Tunisia
Hungary		Belarus	Fiji	Lesotho	Palestine	Tanzania
Ireland		Belize	Gabon	Macao	Qatar	Uganda
Iceland		Bolivia	Gambia	Morocco	Romania	Ukraine
Israel		Brazil	Georgia	Moldova	Russia	Uruguay
Italy		Barbados	Ghana	Madagascar	Rwanda	Uzbekistan
Japan		Brunei	Grenada	Maldives	Saudi Arabia	United Arab Emirates
Lithuania		Bhutan	Guatemala	N.Macedonia	Sudan	Venezuela
Luxembourg		Botswana	Guinea	Mali	Senegal	Vietnam
Latvia		Central African Republic	Guinea-Bissau	Malta	Singapore	Yemen
Mexico		China	Guyana	Myanmar	Sierra Leone	South Africa
Netherlands		Côte d'Ivoire	Montenegro	Mongolia	El Salvador	Zambia
Norway		Cameroon	Haiti	Mozambique	Serbia	Zimbabwe