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Does inflation targeting lead to excessive exchange rate volatility?

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Abstract

This paper analysis whether the adoption of inflation targeting affects excessive exchange rate volatility, i.e. the share of exchange rate fluctuations not related to economic fundamentals. Using a signal-extraction approach to estimate this excessive volatility in multivariate exchange rates in a sample of forty-four countries, the empirical results show no systematic relationship between inflation targeting and excessive exchange rate volatility. Joint analysis of the effects of inflation targeting and EMU membership shows, however, that a membership in the monetary union significantly reduces this excessive volatility. Together, the results suggest that floating exchange rates not only serve as a shock absorber but are also an independent source of shocks, and that these excessive fluctuations in exchange rates can be reduced by joining a monetary union. At the same time the results suggest that adopting inflation targeting does not by itself contribute to excessive exchange rate volatility.

JEL classification: F31; E31; E42; E52; E58.

Keywords: Exchange rate volatility; Exchange rate misalignements; Inflation targeting; Monetary policy regimes.

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1. Introduction

It is sometimes argued that the adoption of inflation targeting (IT) leads to increased volatility of other economic variables, such as output, employment and the exchange rate. In the case of the exchange rate, the argument goes that IT puts too much emphasis on stabilising the domestic value of the currency thus leading to benign neglect of stabilising its external value, ultimately resulting in increased exchange rate volatility.

This observation is true to the extent that most countries that have adopted IT did so after exiting an exchange rate peg or an exchange rate regime that focused on exchange rate stability and thus experienced some increase in exchange rate variability. However, the fact that IT usually requires some exchange rate flexibility which necessarily leads to greater exchange rate variability is not a very interesting or insightful observation. It is obvious that floating exchange rates move more than fixed ones. But at the same time it is also obvious that not all exchange rate movements are economically costly. As exchange rates are relative prices, some exchange rate movement is both necessary and helpful for economic adjustment to shocks. The problem is, however, that a growing number of empirical studies suggests that exchange rates move 'too much', i.e. that exchange rate volatility is greater than is warranted by movements in economic fundamentals. Exchange rates therefore become a source of shocks rather than merely serving as a shock absorber. In the context of the relationship between IT and exchange rate volatility, the real issue is therefore whether IT affects this 'excessive' component of exchange rate variability. This paper attempts to address this issue.

For this, the paper uses a signal-extraction approach designed to extract model noise from rational expectations present-value models to estimate excessive exchange rate volatility from multilateral exchange rates of forty-four countries, ranging from lower-medium income countries to highly developed countries. First, two different generalised autoregressive conditional heteroscedasticity (GARCH) specifications are estimated for each country and then a panel setup is applied where the IT countries serve as a treatment group and the remaining non-targeting countries as a control group. Overall, the results suggest no apparent relationship between IT and excessive exchange rate volatility. The claim that IT leads to detrimental exchange rate volatility is therefore refuted in this country sample.

The country sample used in this study also includes another important monetary policy regime switch, i.e. the establishment of the European Monetary Union (EMU) in 1999. If exchange rates move too much, an entry into a monetary union should see a clear decline in excessive exchange rate volatility. EMU membership can therefore serve as a check on the ability of the framework proposed to detect the relation between monetary policy regimes and excessive exchange rate volatility. The effects of EMU membership are also of interest in itself as the existence of a significant EMU effect on excessive exchange rate volatility lends support to the argument that floating exchange rates are too volatile. Repeating the analysis using the same GARCH specifications as before and the panel specification for testing the EMU effect separately and jointly with the IT effect gives a significant negative relation between

EMU membership and excessive exchange rate volatility. Thus, EMU membership leads to a significant reduction in excessive exchange rate volatility, while the IT effect continues to be insignificant.

The results are found robust to a battery of alterations of the empirical setup: using different IT adoption dates, changing the control group, using cross-sectional difference-in-difference estimation, adding periodic fixed effects, using different specification of the exchange rate volatility measure, changing the timing structure of the monetary policy regime dummies, or using instrumental variables to capture the possibility that the regime changes are endogenous.

The remainder of the paper is organised as follows. Section 2 discusses the IT framework and the empirical literature on the macroeconomic effects of IT, including its possible effects on exchange rates. Section 3 discusses the concept of excessive exchange rate volatility and how to extract it from the data. Section 4 discusses the country sample, while Section 5 presents the empirical analysis on the relationship between IT and excessive exchange rate volatility using both GARCH estimates for individual countries and panel estimates for the country sample as a whole. This section also presents a similar analysis of the effects of EMU membership on excessive exchange rate volatility, both individually and jointly with the IT effect. The section is completed with a wide array of robustness checks. Section 6 concludes.

2. The inflation-targeting framework

2.1. Characteristics of inflation-targeting regimes

The chief characteristic of IT can be said to involve a public announcement of a numerical target to which the central bank commits itself to keep inflation as close as possible through implementation of a forward-looking monetary policy. The bank's inflation forecast several years ahead plays a key role in communicating information about monetary policy and its likely next steps. This commitment to publish regular inflation forecasts based on a credible economic analysis also imposes an important constraint on central bank behaviour. Other important features of the IT framework include a firm emphasis on a broad-based institutional support for the target and transparent decisions and accountability on the part of the central bank, to signal its commitment to the inflation target. The framework is, however, sufficiently flexible to take into account short-term developments in the real economy. IT therefore combines the advantages of a strict monetary policy rule and a pure discretionary monetary policy. Indeed, Bernanke et al. (1999) describe IT as 'constrained discretion', where the target imposes the constraint while the interpretation and implementation provide the flexibility.

2.2. A selective review of the empirical inflation-targeting literature

The literature on the economic effects of IT is ever growing. This section will therefore only touch upon some of the main results. For a recent and more extensive review of key results see, for example, Mishkin and Schmidt-Hebbel (2007).

Among the key findings in this literature are that inflation levels, volatility and persistence have declined after IT adoption (e.g. Bernanke et al., 1999, Corbo et al., 2001, Levin et al. 2004, Mishkin and Schmidt-Hebbel, 2007, and Pétursson, 2005, 2009). Furthermore, some studies suggest that IT adoption has reduced the effects of supply shocks on inflation (Mishkin and Schmidt-Hebbel, 2007) and made inflation more predictable (Corbo et al., 2001). Some studies also find that IT adoption gradually reduces inflation expectations (Johnson, 2002) and provides a firmer long-term anchor for inflation expectations (Levin et al., 2004).

The literature also suggests that these nominal benefits have not been obtained at the cost of lower or more volatile output growth (e.g. Truman, 2003, Pétursson, 2005) and may even have reduced business cycles and the sacrifice ratio (Corbo et al., 2001). Furthermore, Edwards (2007) and Mishkin and Schmidt-Hebbel (2007) find some evidence that IT adoption has reduced the pass-through of exchange rate shocks to inflation. Finally, some studies find that variouse aspects of monetary policy conduct have improved after IT adoption (e.g. Mishkin and Schmidt-Hebbel, 2007). Others, such as Ball and Sheridan (2005) are, however, more sceptical of the benefits of IT over other monetary policy frameworks.

2.3. Inflation targeting and exchange rate volatility

With most IT countries being small open economies, exchange rate developments play a key role for the success of inflation control and therefore for the success of the IT regime. Exchange rate movements are an important channel in the transmission of monetary policy and affect domestic prices directly, through prices of imported goods and indirectly through the effects on domestic demand, net exports, and private sector expectations. Exchange rate movements are also inherently hard to predict. Large exchange rate fluctuations are therefore challenging for inflation control, especially in very small open economies and emerging market economies, where exchange rate pass-through is commonly found to be relatively high (e.g. Pétursson, 2009). Finally, exchange rate movements play an important role in transmitting international shocks into the domestic economy.

Large exchange rate fluctuations can also lead to real allocation problems and to financial instability, all of which one would expect emerging market economies to be particularly vulnerable to, as their financial system tend to be less developed and their currencies less likely to be internationally traded, therefore reducing the ability to hedge against this risk and share it across borders. This is likely to be of special concern where large exchange rate misalignments emerge and the risks of sudden reversals of capital flows rise. The same applies to foreign currency liabilities, which tend to be much more common in emerging market countries compared to their industrial counterparts. These balance-sheet currency mismatches make these economies more vulnerable to a sharp exchange rate depreciation which could trigger a full-blown financial crisis. Furthermore, the potential negative effects of exchange rate volatility on competitiveness and trade volumes are probably of more concern for emerging market countries as they are more trade-dependent and have a relatively large tradable sector. Hedging against such exchange rate risk is also probably more expensive in these countries as their financial system is less developed, as previously mentioned. The relatively less developed foreign exchange markets in emerging market countries also make them more susceptible to a breakdown in the face of large exchange rate fluctuations as investors exit the market and assets denominated in domestic currency suddenly become illiquid.[1]

How IT affects exchange rate volatility is therefore an important policy issue. Yet, there is a surprising lack of studies on this issue compared to the vast literature analysing other economic consequences of IT. This is all the more surprising given the importance of exchange rate movements for economic developments and inflation performance, particularly for emerging market economies, which constitutes a large share of the IT country group.

Furthermore, most of the analysis of the effects of IT on exchange rates focuses on comparing unconditional exchange rate volatility before and after IT or between IT and non-IT countries, leading some economic commentators to conclude that IT leads to increased exchange rate volatility. Such an analysis is, however, of limited interest. Most IT countries adopted IT after exiting a currency peg or some type of managed floating system. As IT necessarily requires a more flexible exchange rate regime (cf. Mishkin and Savastano, 2001), it comes at no surprise that exchange rate variability has increased after IT adoption, reflecting the currency's shock-absorber role. It is not clear, however, how this by itself can be interpreted as a drawback to the IT framework.

An important exception to this type of analysis is Edwards (2007). He estimates GARCH models for seven IT countries and tests whether IT adoption has increased multilateral exchange rate volatility, conditioning on the previous exchange rate regime in each country. His results suggest that IT adoption has not increased exchange rate volatility, once controlling for the previous exchange rate regime, and has in fact tended to reduce volatility in some countries.

In another interesting paper, Sabbán et al. (2004) use a structural VAR approach to identify nominal and real exchange rate shocks. They build upon a growing literature using structural VARs to analyse whether exchange rates play a role as a shock absorber or are more an independent source of shocks (see below). They find that exchange rate movements become more responsive to real shocks after IT adoption which might suggest that the ability of the exchange rate to act as a shock absorber has improved under IT.

These two papers therefore suggest that IT does not lead to increased exchange rate volatility and may even contribute to reducing it. This is consistent with Kuttner and Posen (2000), which show theoretically and empirically (using G3 bilateral exchange rates) how increased transparency of monetary policy, which is generally thought of as a centre piece of the IT framework, leads to increased exchange rate stability.

This paper confirms the above results by looking at the relationship between IT and 'excessive' exchange rate volatility, i.e. the volatility in exchange rates that

[1] For a further discussion see, for example, Ho and McCauley (2003), Jonas and Mishkin (2005), Mishkin and Savastano (2001), and Mishkin and Schmidt-Hebbel (2002).

cannot be contributed to movements in economic fundamentals. This, in my view, is the central issue in analysing the relationship between IT adoption and exchange rate behaviour. If IT contributes to reducing excessive exchange rate volatility, another important positive aspect of IT emerges. However, if IT contributes to increasing excessive exchange rate volatility, the benefits of other aspects of IT have to be weighed against this drawback, which one might expect to significantly reduce the net benefits of IT adoption in emerging market economies and other small open economies.

3. Excessive exchange rate volatility

3.1. Exchange rate disconnect

Since the breakdown of the Bretton-Woods system in the early 1970s, increasing evidence has emerged suggesting that floating exchange rates are much more volatile than can reasonably be explained by economic fundamentals as derived from standard macroeconomic models. Furthermore, fluctuations in exchange rates even seem largely unrelated to variations in these fundamentals, cf. Meese and Rogoff (1983) who show how standard macroeconomic models fail miserably in predicting exchange rate movements, even within sample. What is also intriguing is that these fluctuations, at least in large and developed countries, do not seem to matter much for general macroeconomic performance, cf. Krugman (1989). Flood and Rose (1995) reach a similar conclusion. They find that exchange rate volatility differs significantly between different exchange rate regimes whereas the volatility of economic fundamentals does not. This is the so-called 'exchange rate disconnect' (e.g. Obstfeld and Rogoff, 2000).

This apparent disconnect between exchange rates and economic fundamentals puts serious question marks over the standard notion that a key role of exchange rates is to act as a shock absorber. According to this standard view, an economic shock (e.g. to technology, terms of trade, preferences, etc.) is partially absorbed by the exchange rate, therefore mitigating the (presumably more costly) adjustment in the real economy. If exchange rates fluctuate beyond what is needed to absorb these real economic shocks, they become an independent source of shocks that can even reduce economic welfare (cf. Neumeyer, 1998). In the words of Buiter (2000): "I view exchange rate flexibility as a source of shocks and instability as well as (or even rather than) a mechanism for responding effectively to fundamental shocks originating elsewhere". This result is supported by a growing literature analysing exchange rate volatility within a structural VAR framework. For example, Artis and Ehrmann (2006) and Farrant and Peersman (2006) find that a significant share of nominal and real exchange rate fluctuations is explained by shocks originating in the foreign exchange market itself, which they attribute to movements in a currency risk premium.

Most of the literature has focused on explaining this finding with different types of foreign exchange market imperfections stemming from trading techniques and institutional factors or from investor's irrationality, leading to various types of behaviour that can amplify volatility, cf. the market-microstructure literature (see Evans, 2009 for a recent overview). The excess volatility of exchange rates can, however, also stem from political interference and weak macroeconomic policy institutions (e.g. Neumeyer, 1998, and Kuttner and Posen, 2000). It seems obvious that emerging market economies and very small open economies are particularly vulnerable to these problems and that the relative costs of floating exchange rates in these countries are therefore more relevant when analysing the costs and benefits of IT.

3.2. Measuring excessive exchange rate volatility

Durlauf and Hall (1988, 1989) suggest a general signal-extracting approach for rational expectations present-value models under the presumption that the underlying model is false. In this case, the model is assumed to be a sum of two unobserved components: a combination of the data implied by the specific model under the null, and an unobserved component that can be labelled model noise. The idea is then to perform a signal-extraction exercise on the data to estimate a lower bound for the variance of the noise component. This approach has been used by Durlauf and Hall (1989) to analyse models of stock prices, by Durlauf and Maccini (1995) to analyse inventory models, and by Konuki (1999) to analyse models of exchange rate determination.[2] This approach is used here using the standard monetary model of exchange rate determination as the null model. The three standard building blocks of the model are given by a money-market equilibrium condition, a purchasing power parity condition and an interest rate parity condition

$$m_t - p_t = \varphi y_t - \lambda i_t \tag{3.1}$$

$$p_t = s_t + p_t^* \tag{3.2}$$

$$i_t = i_t^* + \mathrm{E}(s_{t+1} \,|\Theta_t) - s_t + \xi_t \tag{3.3}$$

where m_t is domestic money supply, p_t and p_t^* are the domestic and foreign price levels, respectively, y_t is real domestic output, i_t and i_t^* are the short-term domestic and foreign nominal interest rates respectively, s_t is the multilateral spot exchange rate (the domestic currency price of one unit of a basket of foreign currencies) and $\mathrm{E}(s_{t+1} \,|\Theta_t)$ denotes rational expectations of the one quarter ahead spot rate, conditional on the public information set Θ_t available at time t.

The variable ξ_t denotes deviations from the rational expectations interest rate parity condition, and can be interpreted as a time-varying exchange rate risk premium that investors require to compensate for investing in domestic assets or, alternatively, as capturing deviations from the standard monetary model − i.e. the non-fundamental or misalignment part of the exchange rate.[3]

From (3.1)-(3.3), using the law of iterative expectations and imposing a no-bubble condition, the spot exchange rate can be written as

[2] See Engel and West (2005) for a slightly different approach to analyse models of exchange rate determination.

[3] Flood and Rose (1999) suggest an alternative interpretation of ξ_t in terms of a portfolio balance shock.

$$s_t = \sum_{j=0}^{\infty} \left(\frac{\lambda}{1+\lambda} \right)^j \mathrm{E}(f_{t+j} \,|\Theta_t\,) + \kappa_t \tag{3.4}$$

where f_t denotes the economic fundamentals

$$f_t = \left(\frac{1}{1+\lambda} \right) (m_t - \varphi y_t - p_t^* + \lambda i_t^*) \tag{3.5}$$

and κ_t, capturing exchange rate noise, is given as the expected present value of ξ_t

$$\kappa_t = \sum_{j=0}^{\infty} \left(\frac{\lambda}{1+\lambda} \right)^{j+1} \mathrm{E}(\xi_{t+j} \,|\Theta_t\,) \tag{3.6}$$

By defining the fundamental exchange rate as

$$s_t^* = \sum_{j=0}^{\infty} \left(\frac{\lambda}{1+\lambda} \right)^j f_{t+j} \tag{3.7}$$

i.e. as the perfect foresight exchange rate under the null, the following relation between the actual spot rate and s_t^* is obtained, where the actual rate equals the sum of the expected fundamental rate and exchange rate noise

$$s_t = \mathrm{E}(s_t^* \,|\Theta_t\,) + \kappa_t \tag{3.8}$$

Under the null hypothesis, the assumption of rational expectations implies that

$$\mathrm{E}(s_t^* \,|\Theta_t\,) = s_t^* - \upsilon_t \tag{3.9}$$

where υ_t is the rational expectations forecast error, which satisfies $\mathrm{E}(\upsilon_t \,|\Theta_t\,) = 0$. Inserting this into (3.8) gives

$$s_t - s_t^* = \kappa_t - \upsilon_t \tag{3.10}$$

Hence, a linear projection of $(s_t - s_t^*)$ on the econometrician's information set $\Upsilon_t \subseteq \Theta_t$ gives

$$\mathrm{proj}(s_t - s_t^* \,|\Upsilon_t\,) = \mathrm{proj}(\kappa_t \,|\Upsilon_t\,) = \widehat{\kappa}_t \tag{3.11}$$

where $\mathrm{proj}(x_t \,|\Upsilon_t\,)$ denotes an operator which linearly projects x_t onto the information set Υ_t. A linear projection of $(s_t - s_t^*)$ on Υ_t is therefore the same as a linear projection of κ_t on Υ_t. Finally, by defining

$$\zeta_t = \mathrm{proj}(\kappa_t \,|\Theta_t\,) - \mathrm{proj}(\kappa_t \,|\Upsilon_t\,) = \kappa_t - \widehat{\kappa}_t \tag{3.12}$$

the following is obtained

$$\kappa_t = \widehat{\kappa}_t + \zeta_t \tag{3.13}$$

This implies that the variance of κ_t can be written as a sum of the variance of the two orthogonal components

$$\sigma_{\kappa}^2 = \sigma_{\widehat{\kappa}}^2 + \sigma_{\zeta}^2 \tag{A.14}$$

and, thus, that $\sigma_{\widehat{\kappa}}^2$ gives a lower bound estimate of the true variance of exchange rate noise, σ_{κ}^2. Durlauf and Hall (1989) also show that if the information set Υ_t includes current values of s_t and f_t, this signal extraction approach corresponds to an optimal Kalman filter smoothing estimate of κ_t and that $\widehat{\kappa}_t$ is an optimal predictor of κ_t.[4]

4. The country sample

This section describes the country sample used and the IT dating scheme applied. The sample period used includes quarterly data for the period 1985-2005. There are a few exceptions where quarterly data for the whole period was not available or not used. In most cases this involved the former communist countries in Eastern Europe, where any meaningful economic analysis would usually use data starting in the early 1990s, and countries which have experience hyperinflation episodes, such as Brazil, where the analysis starts 1995 after the *real plan* was adopted.

4.1. The inflation-targeting countries

Since New Zealand pioneered the inflation targeting framework in early 1990, an increasing number of countries have chosen inflation targeting as their monetary policy framework. This study includes twenty-one of those countries, including nineteen current IT countries by year-end 2001, in addition to Finland and Spain, who adopted IT in the early 1990s before joining the EMU in 1999 (see Table 1).[5]

While there is broad agreement in the literature on the general characteristics and definition of inflation targeting (see Pétursson, 2005), there remains some discrepancy on the exact timing of IT adoption in some countries. This is largely because these countries adopted the regime only gradually towards a full-fledged IT. This can make the exact timing of IT adoption somewhat difficult and alternative dates can be argued for, based on which features of targeting framework are deemed necessary for it to be defined as a formal IT framework.

This paper follows Fracasso et al. (2003), which again follow the timing convention in Mishkin and Schmidt-Hebbel (2002), except in Korea, New Zealand and Thailand, where the local central bank has suggested an alternative starting date. There are, however, three exceptions. Fracasso et al. (2003) define the starting date of IT in New Zealand as being April 1988 when a numerical object for inflation was first announced in the New Zealand's Government budget statement. Following

[4] Pétursson (2009) finds that this variance plays a key role in explaining the cross-country variation in inflation volatility, along with monetary policy shocks and the degree of exchange rate pass-through. These three control variables also play a key role, along with the adoption of IT, in explaining the development of inflation volatility over the last two decades.

[5] Peru and the Philippines adopted IT in 2002 and, more recently, Indonesia, Romania and Slovakia in 2005, Turkey in 2006 and Ghana in 2007.

Mishkin and Schmidt-Hebbel (2002), this paper defines the starting date as March 1990 when the first Policy Targets Agreement between the Minister of Finance and the Governor of the newly independent Reserve Bank of New Zealand was published, specifying numerical targets for inflation and the dates by which they were to be achieved. The second country is Chile, where this paper follows Truman (2003) and defines the starting date as September 1990, when the Central Bank of Chile first announced an inflation target, rather than January 1991 as in Fracasso et al. (2003) which is the start of the first calendar year of the new regime. Others, such as Schaechter et al. (2000) define the starting date as September 1999 when the crawling exchange rate peg was abolished and a full-fledged IT regime was finally in place. The third country is Australia, where I follow Schaechter et al. (2000) and assume the starting date as April 1993 when the Reserve Bank of Australia announced the adoption of the new framework, rather than September 1994 when an exact numerical target was first announced (cf. Bernanke et al., 1999, and Ball and Sheridan, 2005).[6] Finally, the IT group used in this paper includes Switzerland, even though the Swiss National Bank does not regard itself as such (see Rich, 2000). Including Switzerland is, however, standard in most IT studies, although Truman (2003) and Ball and Sheridan (2005) are important exceptions.

It is however important to note, as the robustness analysis reported below suggests, that the main empirical results of this paper are not sensitive to the exact specification of the IT adoption dates and the country group.

4.2. The non-targeting countries

The study also includes an additional control group of twenty-three countries, thus giving a total country sample of forty-four countries. The control group includes the remaining ten EMU countries and thirteen other industrial and emerging market countries. The latter thirteen countries were chosen so as to roughly match the income level and size of the IT countries. Of the nineteen current IT countries analysed, fifteen are OECD members, with Iceland being the smallest (PPP adjusted GDP in 2006 of 8.1 billion US dollars) and Mexico being the least developed (PPP adjusted GDP per capita in 2006 of 10.4 thousand US dollars), according to the *CIA World Factbook*. Of the remaining OECD countries, only Turkey falls below Mexico in terms of income (GDP per capita in 2006 of 8.9 thousand US dollars) with Iceland also the smallest OECD member.

For choosing the additional countries, I therefore exclude all non-IT countries falling below Turkey in terms of GDP per capita and below Iceland in terms of GDP levels.[7] After excluding countries where quarterly data for a sufficient time span

[6] Other adoption dates, slightly different from the ones used here have been suggested. In addition to those mentioned in the main text, most of these alternative dates have been proposed by Ball and Sheridan (2005), who argue that the start of the regime should be dated in 1992Q1 in Canada, 1994Q1 in Finland and 1995Q1 in Sweden. Schaechter et al. (2000) have also argued that the adoption date for Israel should be 1997Q2. Furthermore, Truman (2003) argues that the starting date for Mexico should be as early as 1995Q1.

[7] There is, however, one exception with Malta being included although its GDP is only 8.1 billion US dollars so as to add one observation of a very small, open economy to the control group.

was not available, countries which cannot reasonably be described as decentralised market-based economies, and countries which have experienced serious military conflicts within the sample period, I am left with the group of thirteen countries shown in the final column of Table 1.

Table 1. The country sample

Inflation targeting countries	Adoption date	EMU countries	Membership date	Other countries
Australia	1993Q2	Austria	1999Q1	Cyprus
Brazil	1999Q2	Belgium	1999Q1	Denmark
Canada	1991Q1	Finland	1999Q1	Estonia
Chile	1990Q3	France	1999Q1	Hong Kong
Columbia	1999Q3	Germany	1999Q1	Japan
Czech Republic	1998Q1	Greece	2001Q1	Latvia
Finland	1993Q1	Ireland	1999Q1	Lithuania
Hungary	2001Q2	Italy	1999Q1	Malta
Iceland	2001Q1	Luxembourg	1999Q1	Slovakia
Israel	1992Q1	Netherlands	1999Q1	Slovenia
Korea	1998Q2	Portugal	1999Q1	Taiwan
Mexico	1999Q1	Spain	1999Q1	Turkey
New Zealand	1990Q1			United States
Norway	2001Q1			
Poland	1998Q4			
South Africa	2000Q1			
Spain	1994Q4			
Sweden	1993Q1			
Switzerland	2000Q1			
Thailand	2000Q2			
United Kingdom	1992Q4			

Finland and Spain moved from inflation targeting to EMU membership in January 1999.

As the table shows, the control group includes countries ranging from very small emerging market countries, such as Cyprus and Malta, to very large developed countries, such as Japan and the United States, in addition to the highly developed EMU countries. This should give a control group that is sufficiently heterogeneous to offer an interesting comparison to the IT country group which also contains a similarly heterogeneous group of countries ranging from small to large, and from emerging to highly developed. The control group also offers a country set with a wide array of monetary policy frameworks, ranging from exchange rate pegs, currency boards, and monetary union, to floating exchange rates with monetary targets or other hybrid frameworks.[8]

[8]It should be kept in mind that some of these countries do not pursue a truly independent monetary policy for some part of the sample period (e.g. the EMU countries), or a monetary policy that is similar to that of the IT countries (e.g. the European countries, Japan and the United States). This may reduce the number of truly independent observations in the control group and make the identification of the treatment effect more difficult. Including the emerging market countries is therefore important to help reducing this potential identification problem.

5. Empirical results

The first step in obtaining the noise component of exchange rate volatility, $\widehat{\kappa}_t$, is to estimate the money-market relation (3.1) for the sample period available to get values of φ and λ, used to measure the discount factor and calculate the fundamental exchange rate. This is done using the dynamic OLS (DOLS) approach of Stock and Watson (1993) with one lead and lag of the data. For those countries where $\varphi > 1$, a unit income elasticity was imposed. Having obtained estimates of φ and λ, data for the fundamentals from equation (3.5) can be generated using the end-point approximation suggested by Shiller (1981)[9]

$$s_t^* = \sum_{j=0}^{T-t} \left(\frac{\lambda}{1+\lambda} \right)^j f_{t+j} + \left(\frac{\lambda}{1+\lambda} \right)^{T-t} s_T \tag{5.1}$$

The final step is to generate $\widehat{\kappa}_t$. This is done by projecting $(s_t - s_t^*)$ on the information set Υ_t, which is assumed to include a constant and current and four lags of s_t and f_t, using a Newey-West adjusted covariance matrix. This gives the estimated exchange rate noise series $\widehat{\kappa}_t$.

5.1. GARCH estimates of the inflation-targeting effect

Assuming that $\widehat{\kappa}_t$ can be approximated by an AR(1) process[10]

$$\widehat{\kappa}_t = \mu + \rho \widehat{\kappa}_{t-1} + \epsilon_t \tag{5.2}$$

the variance of the estimated model noise $\sigma^2_{\widehat{\kappa}}$, which is a lower bound on the variance of actual model noise as mentioned above, is given as $\sigma^2_{\widehat{\kappa}} = \sigma^2_{\epsilon}/(1-\rho^2)$.

To capture the possible effects of IT on the volatility of exchange rate noise, I first use a GARCH model to capture the possible time-variation of $\sigma^2_{\widehat{\kappa}}$. More specifically, I assume that the time variation of σ^2_{ϵ} can be described by a component GARCH (CGARCH) model which allows for mean reversion in the variance of exchange rate noise to a time-varying long-run level. The CGARCH model thus consists of two components, first a component describing the transitory part, $\sigma^2_{\epsilon,t} - \omega_t$, and a second component describing the long-run time-varying volatility, ω_t

$$\begin{aligned} (\sigma^2_{\epsilon,t} - \omega_t) &= \alpha(\epsilon^2_{t-1} - \omega_{t-1}) + \beta(\sigma^2_{\epsilon,t-1} - \omega_{t-1}) & (5.3) \\ \omega_t &= \varpi + \psi(\omega_{t-1} - \varpi) + \delta(\epsilon^2_t - \sigma^2_{\epsilon,t-1}) + \gamma D_t & (5.4) \end{aligned}$$

[9] In some cases the terminal value of (5.1) tends to jump for the last few observations. To avoid this problem, data for 2006 and observations for what was available for 2007, plus artificial data was used to generate three further years of data. The artificial data was constructed by assuming a 2% annual steady state rate of inflation, a 3% steady state rate of growth, a 5% (the sum of inflation and output growth) steady state growth rate of money and an unchanged interest rate and exchange rate from the last observation. The results are not sensitive to these assumptions.

[10] This is consistent with Backus et al. (1993), who find that the exchange rate risk premium can be approximated by a persistent AR(1) process.

where D_t is a dummy variable that equals unity from the first quarter after IT adoption. This setup therefore allows D_t to affect the permanent component of the variance of exchange rate noise, with the long run variance of ϵ_t changing from ϖ to $\varpi + \gamma/(1-\psi)$ after IT.

Equations (5.3)-(5.4), together with the level equation (5.2), are estimated for each IT country. The estimation period covers the whole period for which $\widehat{\kappa}_t$ is available, which is from 1986Q2-2005Q4 in most cases.[11] The results are shown in Table 2. For comparison, estimation results from a simple EGARCH specification are also reported

$$\log \sigma^2_{\epsilon,t} = \omega + \alpha \left| \frac{\epsilon_{t-1}}{\sigma_{\epsilon,t-1}} \right| + \delta \left(\frac{\epsilon_{t-1}}{\sigma_{\epsilon,t-1}} \right) + \beta \log \sigma^2_{\epsilon,t-1} + \gamma D_t \tag{5.5}$$

A positive IT effect, implying that IT has increased the volatility of exchange rate noise, is found in about half of the countries but the effect is only statistically significant in three of them. Two of those, Poland and South Africa, are emerging market countries while the third one is Iceland; a very small industrial country with a financial system that shares a number of the characteristics of emerging markets with less developed financial systems. At least two of those, Iceland and Poland (at least in the early years of the IT framework), have also experienced some lack of political and institutional commitment to the IT framework. Of the countries where a negative IT effect is found, four are found to be statistically significant: Australia, Switzerland, the United Kingdom, Columbia and Mexico, all of which (at least the first three) are quite successful inflation targeters.

It is interesting that in almost all of the countries where γ is found to be positive are emerging market countries who all have their currencies traded in a relatively thin and less developed foreign exchange markets and are more likely to lack the institutional support for the IT framework. In fact, the median estimate for the emerging market countries (including Iceland) is found to be positive, while it is negative for the more developed countries (excluding Iceland). This suggests that the development and liquidity of the foreign exchange market may play a key role in determining whether IT adoption increases excessive exchange rate volatility. Less developed financial systems and less liquid foreign exchange markets, a typical property of emerging market economies (see Ho and McCauley, 2003), are less likely to be successful in absorbing shocks and distributing and pricing risk. They are also often typified by a lack of important financial contracts or pricing distortions in available ones, and are often susceptible to one-way trading flows, stop-loss trading strategies,

[11] The exceptions are Brazil (from 1996Q2), Chile (from 1987Q2), Columbia (from 1995Q2), the Czech Republic (from 1993Q2), Hungary (from 1992Q2), Israel (from 1988Q1), Poland (from 1992Q1), and Thailand (from 1994Q2). Special dummy variables for changes in indirect taxes were included in the level equation for Australia (2000Q3), Canada (1991Q1 and 1994Q1-Q2), Norway (2003Q1 and 2003Q2) and the UK (1990Q2). Additional dummy variables are included in the level equation for Brazil (1999Q1, reflecting the Brazilian debt crisis), Israel (1998Q4, reflecting the Asian crisis), Mexico (1995Q1, reflecting the Mexican debt crisis), New Zealand (1991Q4, reflecting a large outlier), Sweden (1993Q1, to ensure a positive long-run variance), and Thailand (1997Q3-Q4 and 1998Q1, reflecting the Asian crisis). The dummy variables are unity in the given quarter and zero elsewhere, except the Canadian 1994Q1-Q2 dummy (0.75 in 1994Q1 and 0.25 in 1994Q2).

and herd behaviour. It is, however, worth emphasising that the overall GARCH results show no clear evidence that IT adoption leads to increased excessive exchange rate volatility.

Table 2. GARCH estimates of IT effect on exchange rate noise

	EGARCH model			CGARCH model		
		Long-run variance			Long-run variance	
	IT effect	Before IT	After IT	IT effect	Before IT	After IT
Australia	-1.931 (5.0)	0.400	0.153	-0.00013 (67.7)	0.234	0.131
Brazil	0.002 (0.0)	0.493	0.494	0.00328 (1.3)	0.057	0.741
Canada	0.006 (0.0)	0.080	0.081	0.00016 (0.5)	0.052	0.099
Chile	-0.710 (0.7)	0.274	0.138	-0.00037 (1.3)	0.400	0.137
Columbia	-0.155 (0.7)	0.019	0.013	-0.00015 (2.3)	0.103	0.051
Czech Republic	0.062 (0.3)	0.038	0.042	0.00016 (0.6)	0.042	0.062
Finland	0.243 (0.7)	0.120	0.174	0.00018 (0.3)	0.085	0.189
Hungary	0.024 (0.1)	0.173	0.187	-0.00003 (0.3)	0.075	0.056
Iceland	2.231 (3.3)	0.058	0.265	0.00285 (2.4)	0.061	0.229
Israel	-0.129 (0.6)	0.156	0.089	-0.00010 (0.4)	0.147	0.097
Korea	0.092 (0.2)	0.231	0.258	0.00015 (0.6)	0.166	0.223
Mexico	-0.165 (1.1)	0.251	0.182	-0.00037 (11.1)	0.533	0.358
New Zealand	-0.475 (1.5)	0.238	0.147	-0.00008 (0.2)	0.142	0.123
Norway	0.285 (0.9)	0.039	0.087	0.00023 (1.3)	0.037	0.091
Poland	0.335 (3.2)	0.038	0.106	0.00036 (11.7)	0.058	0.344
South Africa	0.864 (3.6)	0.316	0.942	0.00101 (4.4)	0.154	0.621
Spain	-0.151 (1.5)	0.028	0.000	-0.00006 (0.9)	0.046	0.025
Sweden	0.003 (0.0)	0.054	0.054	0.00019 (0.6)	0.026	0.075
Switzerland	-0.093 (1.1)	0.053	0.031	-0.00009 (8.1)	0.096	0.047
Thailand	-0.191 (0.7)	0.025	0.020	-0.00020 (1.4)	0.118	0.037
United Kingdom	-0.284 (3.1)	0.067	0.023	-0.00024 (1.5)	0.139	0.054

Absolute z-values are in parentheses using Bollerslev-Wooldridge heteroscedasticity consistent variance-covariance estimates. Variances are reported in percentages.

5.2. Estimating the inflation-targeting effect in a multi-country setup

The next step is to analyse the effect of IT on the volatility of exchange rate noise using pooled data, thus utilising both the country and time dimensions of the full sample. In this case, I use three different measures of excess exchange rate volatility. The first is obtained by calculating the variance of $\widehat{\kappa}_t$ using a rolling two year window. The second applies the same method but uses a four year window. The final one is obtained by using the permanent component of a CGARCH model similar to (5.4) above but without the regime-change dummy variable.

Table 3. Descriptive statistics on volatility of exchange rate noise

Measuring variance of exchange rate noise with a rolling 2 year horizon

	All period	Pre-targeting period	Post-targeting period
All countries	0.218	0.253	0.197
IT countries	0.302	0.299	0.288
EMU countries	0.120	0.134	0.078
Other countries	0.231	0.255	0.248
Industrial countries	0.174	0.150	0.136
Emerging market countries	0.464	0.325	0.298

Measuring variance of exchange rate noise with a rolling 4 year horizon

	All period	Pre-targeting period	Post-targeting period
All countries	0.505	0.425	0.438
IT countries	0.634	0.731	0.617
EMU countries	0.284	0.310	0.195
Other countries	0.458	0.313	0.457
Industrial countries	0.356	0.304	0.344
Emerging market countries	0.831	0.731	0.634

Measuring variance of exchange rate noise with a CGARCH model

	All period	Pre-targeting period	Post-targeting period
All countries	0.081	0.081	0.085
IT countries	0.094	0.090	0.089
EMU countries	0.033	0.030	0.025
Other countries	0.090	0.084	0.094
Industrial countries	0.058	0.057	0.057
Emerging market countries	0.118	0.100	0.103

Numbers reported are median variances in percentages. For non-IT and non-EMU countries, the pre-targeting period corresponds to data prior to 1998 and the post-targeting period to the period from 1998.

Table 3 reports median variances for the three measures for the whole country sample and the three different sub-groups, while Figures 1-3 in Appendix A show the individual country data, with solid red vertical lines indicating IT adoption dates and broken green vertical lines EMU membership dates. For the non-IT and non-EMU countries, I use the weighted average IT and EMU adoption date as the break-date, similar to what is commonly done in the empirical IT literature (cf. Mishkin and Schmidt-Hebbel, 2007). This gives a break-date at 1998Q1, i.e. the pre-targeting period is 1985-1997 while the post-targeting period is 1998-2005.

Although the actual level of excessive exchange rate volatility differs slightly across the three different variance measures, excessive volatility seems to have declined in the post-targeting period, especially in the EMU countries. The table also reports median variances for industrial and emerging market countries, clearly showing that the volatility of exchange rate noise is higher in emerging market countries than in the industrial ones.

Table 4. Panel estimates of IT effect on exchange rate noise

Measuring variance of exchange rate noise with a rolling 2 year horizon

	Group 1		Group 2	
	Fixed	Random	Fixed	Random
IT coefficient estimate	-0.00014	-0.00008	-0.00014	-0.00008
t-value	1.03	0.63	1.04	0.58
Number of observations	2,826	2,826	2,328	2,328
Standard error of regression	0.0017	0.0017	0.0017	0.0017
First order serial correlation	0.21	0.13	0.31	0.21

Measuring variance of exchange rate noise with a rolling 4 year horizon

	Group 1		Group 2	
	Fixed	Random	Fixed	Random
IT coefficient estimate	-0.00007	-0.00003	-0.00007	-0.00003
t-value	0.65	0.35	0.65	0.28
Number of observations	2,607	2,607	2,127	2,127
Standard error of regression	0.0013	0.0013	0.0013	0.0013
First order serial correlation	0.73	0.50	0.82	0.65

Measuring variance of exchange rate noise with a CGARCH model

	Group 1		Group 2	
	Fixed	Random	Fixed	Random
IT coefficient estimate	0.00005	0.00010	-0.00001	0.00004
t-value	0.52	1.10	0.13	0.39
Number of observations	2,909	2,909	2,404	2,404
Standard error of regression	0.0015	0.0015	0.0013	0.0013
First order serial correlation	0.88	0.79	0.57	0.50

T-values are absolute values obtained using robust cross-section panel corrected standard errors. The random effect specification is estimated using feasible GLS. The test for first-order serial correlation reports p-values. The first country group includes all the 44 countries used in the paper: the 21 IT countries and a control group of 23 additional countries. The second country group includes 34 countries: the 21 IT countries and a control group of 13 industrial countries.

To formally estimate the possible effect of IT adoption in a panel setup, the following model is estimated

$$V_{j,t} = \upsilon + \theta(L)V_{j,t-1} + \gamma D_{j,t} + \eta_j + \varepsilon_{j,t} \tag{5.6}$$

where $V_{j,t}$ is the volatility of exchange rate noise in country j in period t, υ is the overall constant in the model, η_j is a country-specific effect (either assumed to be fixed or random), $\varepsilon_{j,t}$ is an error term and D_t is the inflation target dummy that equals unity from the first quarter after IT adoption if country j is a targeter but zero throughout for non-targeters.[12] $\theta(L)$ is a lag polynomial in the dependent variable controlling for the persistence in the volatility of exchange rate noise discussed above (which can either be intrinsic or reflect other omitted determinants of volatility). Two lags were needed for $V_{j,t}$ using the rolling-window variances but one was sufficient for $V_{j,t}$ from the CGARCH model to ensure that the residual autocorrelation is insignificant. The random effect specification is estimated using feasible GLS and t-values are obtained using robust cross-section panel corrected standard errors.

Table 4 reports the results using a panel with two alternative control groups: first, all the additional twenty-three countries used in the study; and second, a sample of thirteen industrial countries.[13] Both control groups give rise to a large panel sample of between 2,127-2,909 observations. As can be seen from the table, the IT effect is found to be negative in all cases except in some instances when the CGARCH model is used to measure $V_{j,t}$. The effects are, however, very imprecisely estimated and the t-values therefore very small. The results therefore seem to corroborate the findings from the GARCH models for individual countries, i.e. that there is no evidence that IT adoption increases excessive volatility in exchange rates. As the table shows, the results are found to be robust to using either fixed or random country effects and Hausman tests provide little evidence against the null hypothesis that there is no misspecification.

5.3. Comparing the effects of inflation targeting and EMU membership

The country sample also includes twelve European countries that experienced another major change in their monetary policy regime, when they joined a monetary union in 1999 (or 2001 in the case of Greece). If exchange rates move too much, an entry into a monetary union should see a clear decline in excessive exchange rate volatility. EMU membership can therefore serve as a check on the ability of the framework proposed to detect the relation between monetary policy regimes and excessive exchange rate volatility. The effects of EMU membership are also of interest in itself as the existence of a significant EMU effect on excessive exchange rate volatility lends support to the argument that floating exchange rates are too volatile.

Table 5 reports the results from the two GARCH models for the EMU countries. The estimation period is again 1986Q2-2005Q4.[14] The EMU effect is found to be negative in eleven of the twelve EMU countries (or ten in the EGARCH model) and is found to be significantly negative in nine of the countries (in either GARCH specifications). In none of the cases where a positive sign on γ is found, are the EMU effects found to be statistically significant from zero.[15]

[12] In the case of Finland and Spain, the IT dummy becomes zero again from 1999Q1.

[13] The industrial countries are Austria, Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Japan, Luxembourg, the Netherlands, Portugal and the United States.

[14] The exceptions are Austria (from 1989Q2), Ireland (from 1987Q1), and Portugal (from 1996Q2). The GARCH models include a dummy variable in the level equation for France (1992Q4, reflecting the ERM crisis), Ireland (1990Q4, reflecting a large outlier), and Italy (1992Q4 and 1993Q1, reflecting the ERM crisis). The dummy variables are unity in the given quarter and zero elsewhere.

[15] Allowing also for the previous IT adoption in Finland and Spain only strengthens the negative

The GARCH models therefore suggest that EMU membership has reduced the volatility of exchange rate noise. The median point estimate for the unconditional standard deviation of exchange rate noise falls from 2.3% to 1.4% in the CGARCH model (from 1.9% to 1.4% in the EGARCH model), or by roughly a quarter.

Table 5. GARCH estimates of EMU effects on exchange rate noise

	EGARCH model			CGARCH model		
		Long-run variance			Long-run variance	
	EMU effect	Before EMU	After EMU	EMU effect	Before EMU	After EMU
Austria	-0.398 (1.0)	0.017	0.012	-0.00001 (2.6)	0.021	0.015
Belgium	0.030 (0.1)	0.021	0.022	-0.00001 (5.6)	0.027	0.023
Finland	-0.896 (2.8)	0.146	0.044	-0.00032 (2.1)	0.219	0.011
France	0.003 (0.0)	0.028	0.028	0.00008 (0.6)	0.021	0.036
Germany	-0.178 (4.8)	0.042	0.029	-0.00015 (1.2)	0.055	0.026
Greece	-0.300 (0.8)	0.064	0.035	-0.00003 (0.8)	0.050	0.022
Ireland	-0.063 (1.6)	0.031	0.014	-0.00005 (2.1)	0.075	0.004
Italy	-0.267 (0.3)	0.130	0.099	-0.00013 (1.6)	0.107	0.026
Luxembourg	-0.921 (1.0)	0.075	0.019	-0.00031 (3.3)	0.110	0.023
Netherlands	-0.183 (4.5)	0.013	0.008	-0.00001 (1.1)	0.022	0.016
Portugal	-0.216 (1.1)	0.012	0.008	-0.00001 (11.9)	0.017	0.010
Spain	-1.721 (3.1)	0.058	0.020	-0.00009 (24.9)	0.066	0.003

Absolute z-values are in parentheses using Bollerslev-Wooldridge heteroscedasticity consistent variance-covariance estimates. Variances are reported in percentages.

This fall in excess exchange rate volatility implied by the GARCH estimates is confirmed by the panel results. Table 6 redoes the panel analysis while adding an EMU dummy variable to the panel specification in (5.6) and testing jointly for the effects of IT and EMU membership. Note that the distinction between treatment and control groups becomes slightly more complicated in this case. The analysis includes nineteen current IT countries plus the twelve EMU countries, but accounting for the temporary IT adoption of Finland and Spain. Because the IT and EMU effects are analysed jointly, the IT countries act as a control for the EMU effect and vice versa for the IT effect. There are in addition thirteen countries in the first country sample that act as a pure control and three additional countries in the latter industrial country group.

EMU effect, while also giving a significantly negative IT effect in both countries.

Table 6. Panel estimates of IT and EMU effects on exchange rate noise

Measuring variance of exchange rate noise with a rolling 2 year horizon

	Group 1		Group 2	
	Fixed	Random	Fixed	Random
IT coefficient estimate	-0.00015	-0.00009	-0.00015	-0.00009
t-value	1.08	0.71	1.08	0.66
EMU coefficient estimate	-0.00014	-0.00019	-0.00014	-0.00019
t-value	2.53	2.95	2.52	2.86
Number of observations	2,826	2,826	2,328	2,328
Standard error of regression	0.0017	0.0017	0.0017	0.0017
First order serial correlation	0.20	0.20	0.31	0.22

Measuring variance of exchange rate noise with a rolling 4 year horizon

	Group 1		Group 2	
	Fixed	Random	Fixed	Random
IT coefficient estimate	-0.00007	-0.00004	-0.00007	-0.00003
t-value	0.69	0.43	0.69	0.36
EMU coefficient estimate	-0.00007	-0.00010	-0.00008	-0.00010
t-value	1.64	2.03	1.66	1.93
Number of observations	2,607	2,607	2,127	2,127
Standard error of regression	0.0013	0.0013	0.0013	0.0013
First order serial correlation	0.73	0.50	0.82	0.65

Measuring variance of exchange rate noise with a CGARCH model

	Group 1		Group 2	
	Fixed	Random	Fixed	Random
IT coefficient estimate	0.00005	0.00009	-0.00002	0.00003
t-value	0.51	0.99	0.16	0.31
EMU coefficient estimate	-0.00003	-0.00011	-0.00005	-0.00010
t-value	1.92	2.88	3.06	2.99
Number of observations	2,909	2,909	2,404	2,404
Standard error of regression	0.0015	0.0015	0.0013	0.0013
First order serial correlation	0.88	0.80	0.57	0.50

T-values are absolute values obtained using robust cross-section panel corrected standard errors. The random effect specification is estimated using feasible GLS. The test for first-order serial correlation reports p-values. The first country group includes all the 44 countries used in the paper: the 21 IT countries, the 12 EMU countries (with Finland and Spain switching between the IT and EMU groups) and a pure control group of 13 additional countries. The second country group only uses a pure control group of 3 industrial countries.

As the results in Table 6 show, the IT effect continues to be insignificant from zero, while the EMU effect is significantly negative at the 5% critical level in almost all cases and at the 10% critical level in all instances. The point estimates of the EMU effects, taking into account the lagged dynamics of $V_{j,t}$, suggest a long-run EMU effect ranging from 0.01% in the fixed effect specification using the CGARCH estimate of $V_{j,t}$ to 0.25% in the random effect specification using the four year rolling window estimate of $V_{j,t}$. Using the pre-targeting median values of $V_{j,t}$ from Table 3 therefore implies an average decline in the standard deviation of exchange rate noise (across the three volatility measures and different panel model specifications) from 4.0% in the period prior to EMU membership to 2.3% after EMU membership, or by 1.7 percentage points on average which amounts to a reduction of roughly 40%, a somewhat larger effect than obtained in the GARCH analysis. EMU membership therefore seems to lead to a sizeable reduction in excessive exchange rate volatility, while IT apparently has no effect.[16] The results are found to be robust to using either fixed or random country effects and Hausman tests provide little evidence against the null hypothesis that there is no misspecification.

5.4. Robustness checks

This section addresses whether the results are robust to a number of alternative specifications of the estimated models, dating of policy regime changes and control groups. Overall, the results seem very robust (further detail on the results of these robustness tests is available from author).

5.4.1. Alternative inflation targeting dates and control groups

Timing of inflation target adoption As previously discussed, the literature has proposed several alternative dates for some targeting countries. An important question is therefore how robust the results are to changes in the timing of IT adoption. To analyse this, I look at countries where the adoption dates suggested are four quarters or more away from the dates used in this paper (either earlier or later). The alternative dates chosen are from Ball and Sheridan (2005): 1994Q4 for Australia, 1992Q1 for Canada, 1994Q1 for Finland and 1995Q1 for Sweden; Schaechter et al. (2000): 1999Q3 for Chile and 1997Q2 for Israel; Truman (2003): 1995Q1 for Mexico; and Fracasso et al. (2003): 1988Q2 for New Zealand. Finally, since some studies argue that Switzerland should not be treated as an IT country (cf. Truman, 2003), Switzerland is excluded from the IT group.

Adopting these alternative IT dates and excluding Switzerland from the treatment group does not alter the panel regression results in any way. However, individual GARCH results for some countries change: the IT effect is no longer found to be significant in Mexico but in the EGARCH model it becomes significantly positive in Israel and significantly negative in New Zealand.

Specification of control group In the baseline panel regressions, the volatility of exchange rate noise in IT and EMU countries is compared to two different control groups including non-IT countries and non-EMU members. An alternative approach is to compare the treatment countries to their own pre-treatment experience, i.e. to exclude all non-IT countries from the panel in the IT case and all non-EMU countries in the EMU case. The results remain unchanged when looking at a panel of all IT countries: the IT effect remains insignificant from zero. However, when looking at some subsamples of veteran targeters, such as the thirteen countries who had

[16] Focusing only on the EMU effect and including the IT countries in the treatment group gives identical results.

adopted IT prior to 2000 or the seven countries who had adopted IT prior to 1999 and have a history of low inflation prior to IT, the IT effect becomes significantly negative for some specifications of $V_{j,t}$. As for the EMU countries, the EMU effect remains significantly negative for both rolling-window measures of $V_{j,t}$ (although the point estimates tend to be slightly lower) but becomes insignificant from zero for the CGARCH measure of $V_{j,t}$.

5.4.2. Alternative model specifications and estimation methods

Difference-in-difference cross-section specification A common approach in analysing the economic effects of regime changes, such as IT, is to use the so-called difference-in-difference estimator (see, for example, Ball and Sheridan, 2005 and Mishkin and Schmidt-Hebbel, 2007). In this case the following cross-section specification of equation (5.6) is estimated

$$V_{j,post} - V_{j,pre} = \pi_0 + \pi_1 D_j + \pi_2 V_{j,pre} + u_j \tag{5.7}$$

where $V_{j,post}$ is the variance of exchange rate noise after IT, $V_{j,pre}$ is the variance of exchange rate noise prior to IT, π_0, π_1 and π_2 are reduced form coefficients, and u_j is an error term. Equation (5.7) therefore measures the IT effect taking initial conditions into account, i.e. the pre-targeting level of exchange rate noise variability, using 1998Q1 as the break-date for non-targeting countries, as previously explained. Equation (5.7) is thus estimated for the whole country sample, using the nineteen current IT countries as the treatment group and the other twenty-three countries as the control group, using four measures of exchange rate noise volatility: sample averages of the three time-varying volatility measures previously described and the simple sample variance of $\widehat{\kappa}_t$. The results are found to be the same as in the baseline case: in all four cases does the IT effect remain statistically insignificant from zero.

Repeating the analysis using the twelve EMU members as the treatment group and the remaining thirty-two countries as the control group continues to give a significantly negative EMU effect at the 1% critical level in all cases. Furthermore, allowing for a simultaneous analysis of both treatments (IT and EMU) with a pure control group of thirteen countries also gives a significantly negative EMU effect at the 5% critical level in all but one cases and at the 10% critical level in all cases (again finding an insignificant IT effect in all cases).

Periodic fixed effects The panel regressions in Tables 4 and 6 only include country-specific dummies to account for a different level of volatility of exchange rate noise in each country. Time-specific dummies can also be added, capturing potential common time variation across countries not captured by the dynamics of equation (5.6). Allowing for cross-country and periodic fixed effects, however, gives very similar results to those reported in Tables 4 and 6. The only change is that the EMU effect becomes insignificant from zero when $V_{j,t}$ is defined as the permanent component from the CGARCH model. However, Hausman tests provide little evidence against the null hypothesis that the periodic fixed effects are redundant.

Specification of the variance of exchange rate noise A common practice in cross-country comparison of economic variables is to use the log transformation $\log(1+V_{j,t})$ instead of $V_{j,t}$ directly. This is done to downweight very large observations which may occur in this analysis during periods of very high inflation and extreme exchange rate volatility. The drawback of such a transformation, however, is that it overweights observations that are close to zero. Using this transformation in the panel regressions gives very similar results to those shown in Tables 4 and 6.

Lagged regime dummies A potential endogeneity bias may arise as the regime dummies are entered contemporaneously in the GARCH and panel regressions. One way to reduce this problem is to use one-quarter lags of the IT and EMU dummies. The results of the panel regressions remain identical, but this leads to slight changes in the GARCH results. The IT effect becomes significantly negative in two additional countries, Chile and Thailand, but is no longer found significantly negative in Columbia. Furthermore, the positive IT effect in Iceland becomes insignificant. As for the EMU effect, it is now found to be insignificant from zero in Ireland but becomes significantly negative in the Netherlands. There are also instances where the regime dummies become non-significant from zero in one of the GARCH models but remain significant in the other (Australia and Spain), or switch between models compared to the baseline results (Mexico).

Instrumental variables If IT adoption or EMU membership is endogenous with respect to volatility of exchange rate noise, simply using lagged regime dummies may not be sufficient to address the potential endogeneity problem in the panel regressions. Therefore, an instrumental variable approach is needed. Due to the lack of obvious instruments for the regime dummies, a common choice in the literature is to use lagged values of the regime dummies and past inflation performance (see, e.g. Mishkin and Schmidt-Hebbel, 2007, for the case of the IT dummy, and Breedon and Pétursson, 2006, for the case of the EMU dummy). I therefore use as instruments a one-quarter lag of the IT dummy (or the IT and EMU dummies in the panel regression in Table 6), lags of $V_{j,t}$ and the average pre-targeting inflation in the IT countries (and average pre-EMU inflation in Table 6), and average pre-1998 inflation for non-IT and non-EMU countries, as previously explained. I also tried using a four-quarter moving average of inflation lagged by two years (the exact choice of lag length does not matter) instead of the historical average above. The results remained very similar to the ones reported in Tables 4 and 6 in all cases.

6. Conclusions

The experience of the post Bretton-Woods period clearly shows that floating exchange rates can be very volatile. In fact, a growing literature suggests that exchange rates tend to fluctuate by far more than can reasonably be explained by movements in economic fundamentals. This raises the question of how useful exchange rates really are as a mechanism of adjustment in the face of economic shocks. If exchange rates fluctuate 'too much' they become an independent source of shocks as well as (or instead of) being a shock absorber. Another challenging question in this context is what role the monetary policy regime plays in generating this 'excessive' exchange rate volatility. This is the topic of this paper. More specifically, the question asked is whether the adoption of inflation targeting (IT) can lead to more frequent exchange rate misalignments, i.e. whether this excessive component of exchange rate volatility increases with IT.

The paper therefore makes a clear distinction between the effects of IT on the unconditional variability of exchange rates and the excessive volatility of exchange rates. The former typically increases after IT, but that observation is neither very interesting nor insightful. Since IT has usually been adopted after exiting a rigid exchange rate regime, it is to be expected that exchange rate variability increases when IT is adopted. Furthermore, it is not clear whether that is to be viewed as a drawback, as some exchange rate variability is economically efficient as a tool to adjust relative prices in the face of shocks. Whether IT affects the excessive (or noise) component of exchange rate volatility is, however, a much more fundamental question. If IT contributes to reducing this excessive exchange rate volatility it improves the shock-absorber ability of the currency and another important positive aspect of IT emerges. However, if IT contributes to increasing excessive exchange rate volatility it reduces its shock-absorber ability and the benefits of other aspects of IT have to be weighed against this drawback, which one might expect to significantly reduce the benefits of IT adoption in emerging market economies and other small open economies with small currencies.

To tackle this issue, the paper adopts a signal-extraction approach to estimate the excessive exchange rate volatility from multilateral exchange rates of forty-four countries ranging from lower-medium income countries to highly developed countries. Different GARCH specifications are then estimated for each country and a panel model for the whole country group, using the IT countries as a treatment group and the remaining non-targeting countries as a control group. The results seem clear: there is no evidence that IT leads to greater excessive exchange rate volatility. Although the GARCH results suggest that this volatility has increased after IT in few of the countries, they also suggest that excessive volatility has declined after IT in some of the others countries. A closer inspection of the countries in question suggests that these results may have more to do with characteristics of the foreign exchange markets and institutional support for the IT regime rather than IT adoption by itself.

The country sample used in this study also includes another important monetary policy regime switch, i.e. the establishment of the European Monetary Union (EMU) in 1999. Given that floating exchange rates are excessively volatile, this regime change should offer an obvious chance to check the ability of the framework proposed to detect the relation between monetary policy regimes and this excessive volatility. Analysing the effects of EMU membership is also of independent interest as the existence of a significant EMU effect on excessive exchange rate volatility lends support to the argument that floating exchange rates are too volatile. Repeating the analysis using the same GARCH specifications as before, and the panel specification for testing the EMU effect separately and jointly with the IT effect, gives a significant negative relation between EMU membership and excessive exchange rate volatility. Thus, EMU membership leads to a significant reduction in excessive exchange rate volatility, while IT continues to have no effects. These results are found to be robust to a wide array of robustness tests.

So to sum up: Yes, floating exchange rates seem to be excessively volatile relative to economic fundamentals and membership in a monetary union will reduce this excessive volatility. But the adoption of inflation targeting does not contribute to this excessive volatility by itself. It seems clear however that some countries are more equipped to embrace a floating exchange rate regime. The key factors there are a sufficiently deep and efficient foreign exchange market and a strong institutional support for the nominal anchor chosen rather than whether this anchor is an inflation target or not.

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Appendix A: Country estimates of variance of exchange rate noise

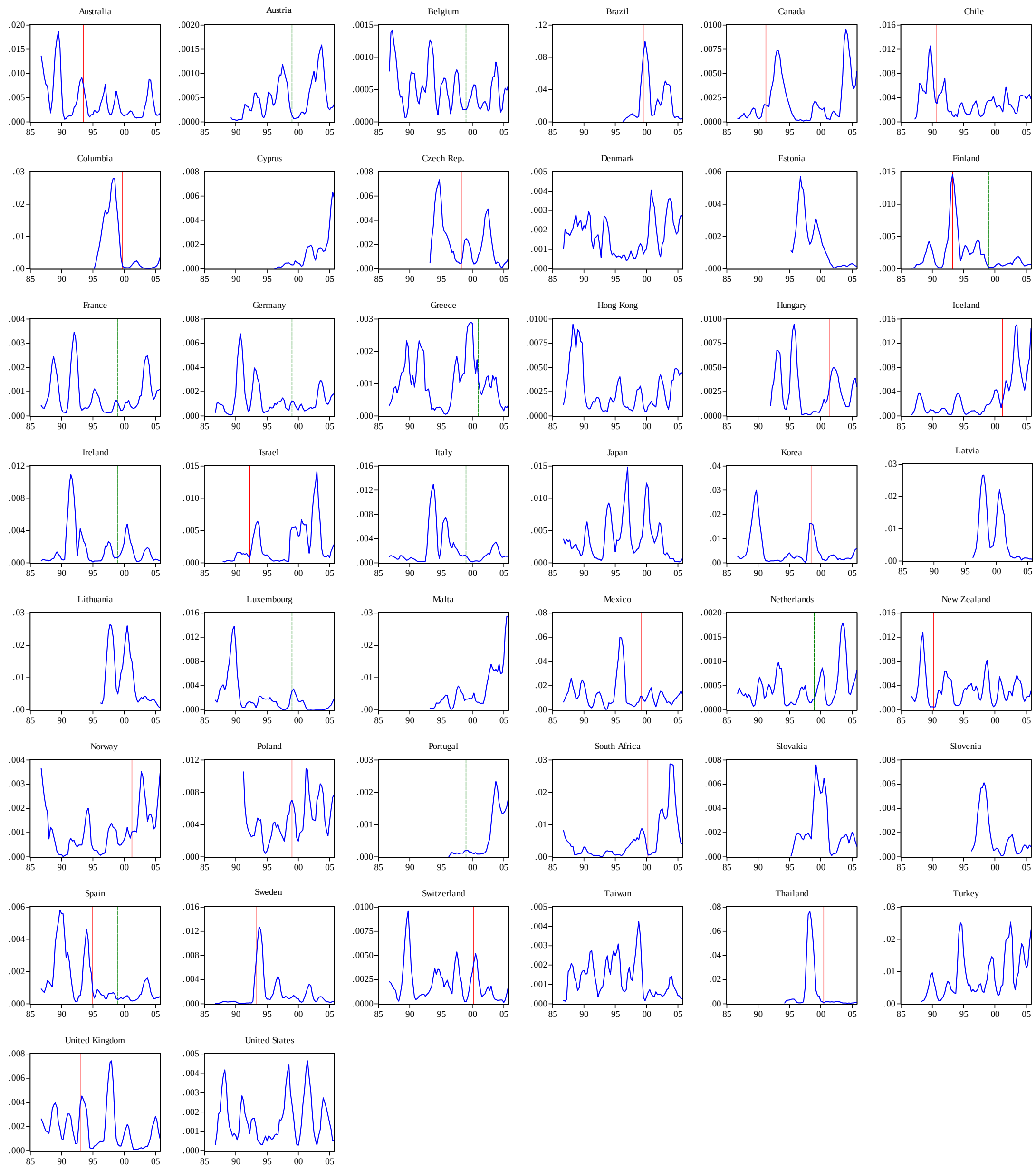

Figure 1. Volatility of exchange rate noise (2 year rolling window variances)

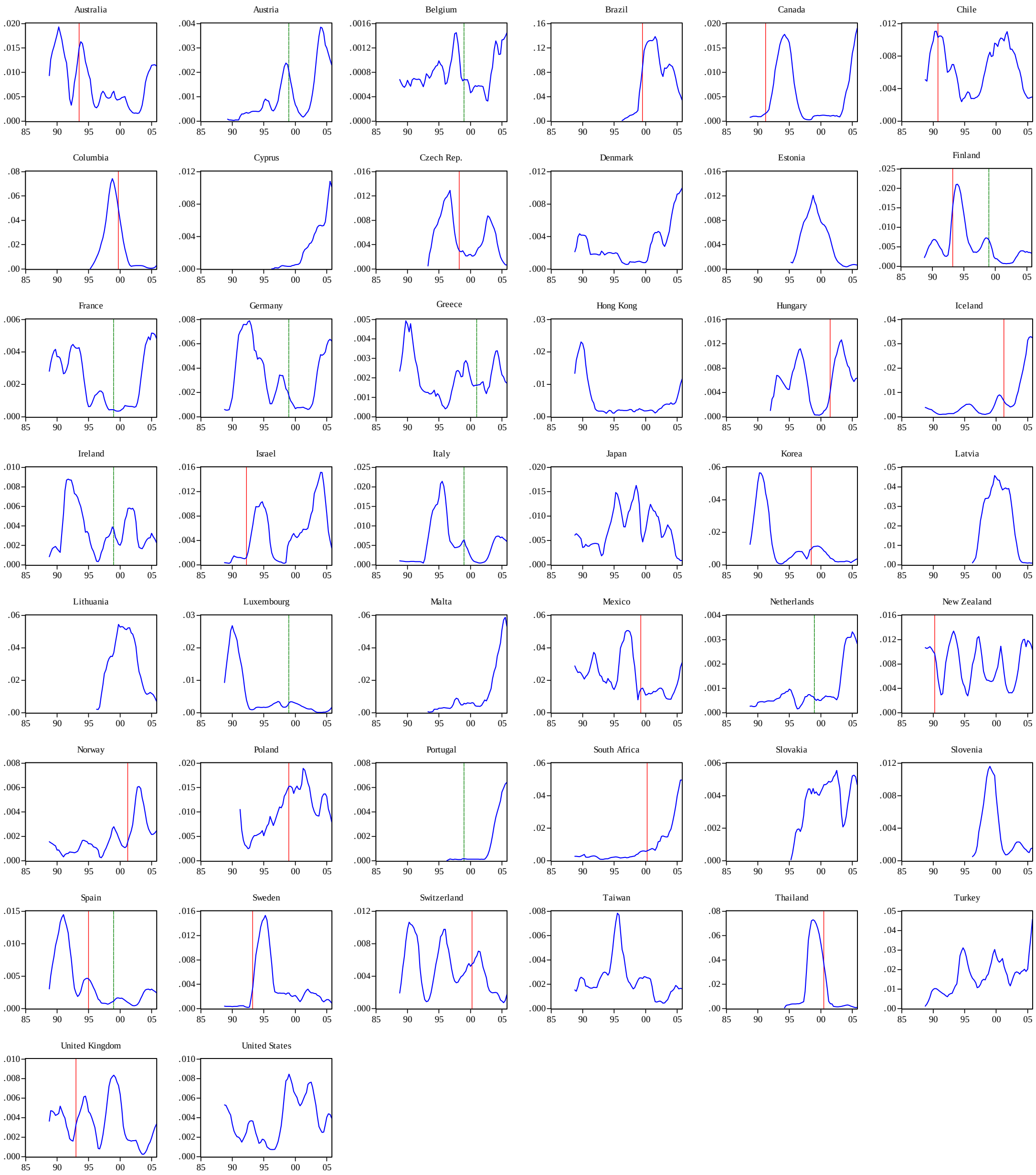

Figure 2. Volatility of exchange rate noise (4 year rolling window variances)

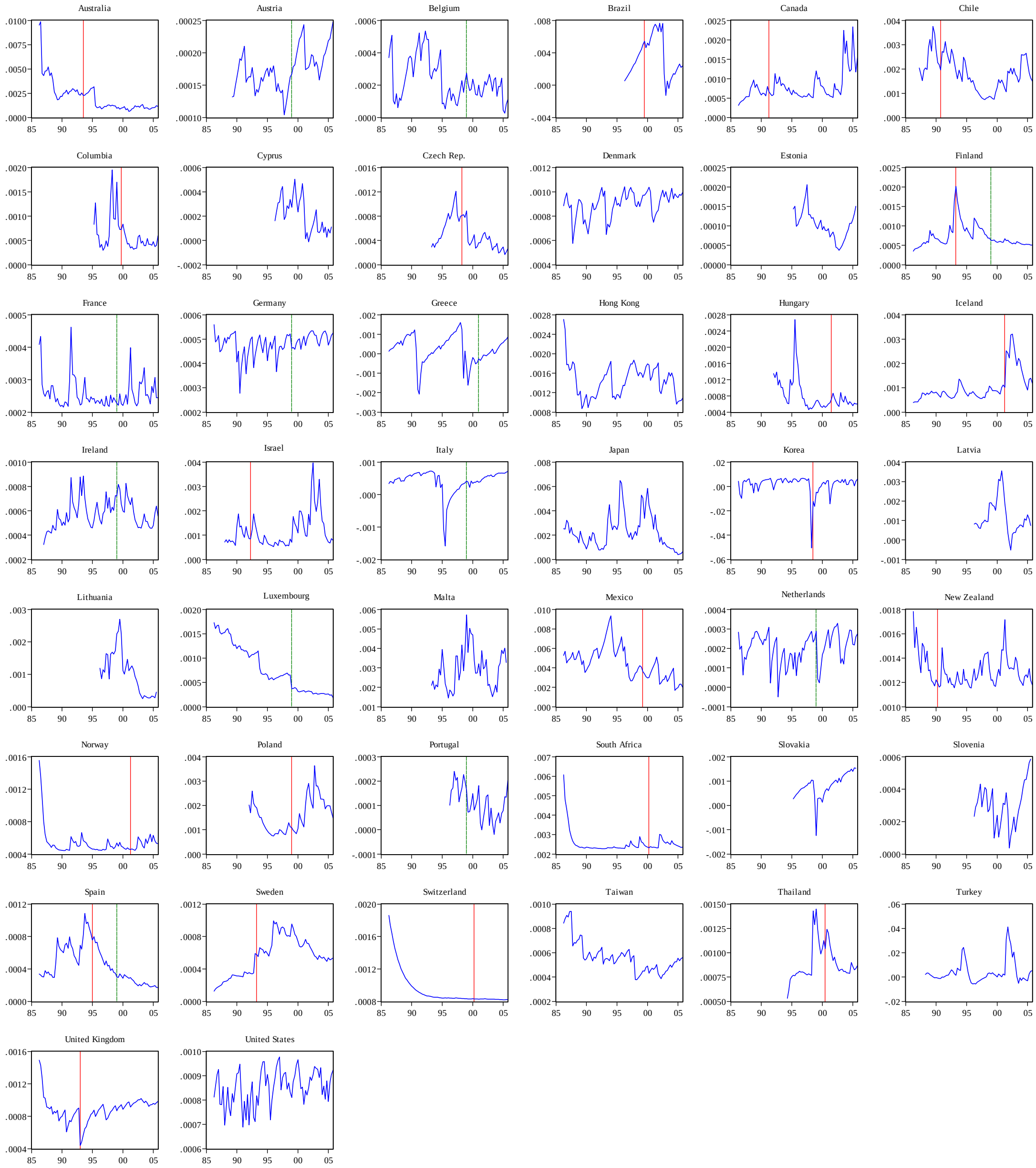

Figure 3. Volatility of exchange rate noise (CGARCH model)

Appendix B: Data sources and description

Consumer price data Quarterly data on the *headline consumer price index* for the period 1985-2005, except for the Czech Republic (from 1989Q1), Estonia (the implicit private consumption price deflator from 1993Q1), Latvia (from 1993Q1), Lithuania (the implicit private consumption price deflator from 1995Q1), Malta (from 1990Q1), Slovakia (from 1993Q1) and Slovenia (the implicit private consumption price deflator from 1995Q1).

All the data are seasonally adjusted from source or by the author using X-12. The data source is Reuters-EcoWin, except for Estonia, Lithuania and Slovenia (data from Eurostat); and Iceland, Israel, Malta and Slovakia (data from national central bank or statistical office).

Exchange rate data Quarterly data on the *effective exchange rate index* for the period 1985-2005, except for Columbia (from 1994), Cyprus (from 1994Q1), the Czech Republic (from 1991Q1), Estonia (from 1994Q1), Israel (from 1986Q4), Latvia (from 1994Q1), Lithuania (from 1994Q1), Malta (from 1990Q1), Slovakia (from 1994Q1) and Slovenia (from 1994Q1). Defined as the value of the domestic currency per one unit of foreign currencies.

The data source is Eurostat, except for Brazil, Chile, Korea, Luxembourg, Mexico, Poland, South Africa, Taiwan and Thailand (data from Reuters-EcoWin and IFS); the Czech Republic and Hungary (data from Eurostat and IFS); and Hong Kong, Iceland, Israel and Malta (data from national monetary authority and central bank).

Interest rate data Quarterly data on the *short-term interest rate* for the period 1985-2005, except for Columbia (from 1986), Cyprus (from 1993Q1), the Czech Republic (from 1993Q1), Estonia (from 1996Q1), Hungary (from 1987Q1), Iceland (from 1988Q4), Israel (from 1986Q1), Latvia (from 1993Q4), Lithuania (from 1994Q3), Malta (from 1993Q1), Slovakia (from 1994Q1), Slovenia (from 1998Q2) and Turkey (from 1993Q1).

The interest rate is a short-term money market rate, except for Chile (commercial bank deposit rate for 1985-1995 and money market rate from 1996), Cyprus (t-bill rate for 1993-1998 and money market rate from 1999), Iceland (Central Bank of Iceland policy rate), Israel (discount rate for 1985-1987 and Bank of Israel policy rate from 1988), Lithuania (t-bill rate for 1994-1998 and money market rate from 1999), Malta (t-bill rate for 1993-1994 and money market rate from 1995), Poland (short-term interest rate from 1991Q3), Taiwan (31-90 days CP rates) and Thailand (money market rate (weighted average of all maturities) for 1985-1996, 3 month repo rate for 1997-2002 (up to May), 3 month SWAP rate for 2002 (from June)-2004, 3 month BIBOR rate for 2005).

The data source is Reuters/EcoWin, except for Cyprus, Estonia, Latvia, Lithuania, Malta, Slovakia, Slovenia and Turkey (data from Eurostat); Hong Kong, Iceland, Taiwan and Thailand (data from national monetary authority or central bank); Chile and Israel (data from national central bank and IFS); and Germany, Hungary and Korea (data from Reuters-EcoWin and IFS).

Money supply data Quarterly data on *broad money* (M2 or M3 depending on availability) for the period 1985-2005, except for Chile (from 1986Q1), Cyprus (from 1990Q1), the Czech Republic (from 1992Q1), Estonia (from 1993Q1), Hungary (from 1990Q4), Latvia (from 1993Q1), Lithuania (from 1993Q2), Malta (from 1992Q1), Poland (from 1989Q4), Slovakia (from 1993Q1) and Slovenia (from 1993Q1).

All the data are seasonally adjusted from source or by the author using X-12. The data source is Reuters-EcoWin, except for Cyprus, Denmark, Estonia, Latvia, Lithuania, Malta, Slovakia and Slovenia (data from Eurostat); Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal and Spain (data from Reuters-EcoWin up to 1998 linked with Euroarea money supply from 1999 from Eurostat); New Zealand (data on M1 from national central bank linked with M3 from 1985 to 1987Q1); and Iceland, Israel and Sweden (data from national central bank).

GDP data Quarterly data on *GDP* for the period 1985-2005, except for Austria (from 1988Q1), Brazil (from 1991Q1), Chile (from 1986Q1), Cyprus (from 1995Q1), the Czech Republic (from 1990Q1), Estonia (from 1993Q1), Latvia (from 1995Q1), Lithuania (from 1995Q1), Malta (from 1990Q1), Poland (from 1990Q1), Portugal (from 1995Q1), Slovakia (from 1993Q1), Slovenia (from 1995Q1), Thailand (from 1993Q1) and Turkey (from 1987Q1).

All the data are constant price and seasonally adjusted from source or by the author using X-12. The data source is Reuters-EcoWin, except for Austria, Belgium, Cyprus, Denmark, Estonia, Greece, Latvia, Lithuania, the Netherlands, Slovakia, Slovenia and Spain (data from Eurostat); Columbia (data from Reuters-EcoWin and IFS); the Czech Republic and Hungary (Reuters-EcoWin and Eurostat); Chile, Iceland, Israel, Malta (data from national monetary authority or central bank); and Ireland and Sweden (data from Reuters-EcoWin and national central bank or statistical office).

International data *Consumer prices:* Quarterly data on OECD countries excluding high inflation countries (Hungary, Mexico, Poland and Turkey) from Reuters-EcoWin. Seasonally adjusted using X-12. *GDP:* Quarterly data on OECD (original 25 members) for the period 1985-2005 from Reuters-EcoWin. Seasonally adjusted from source. *Interest rate:* Quarterly data on weighted average of OECD countries (from *OECD Main Economic Indicators*), excluding high inflation countries (Hungary, Mexico, Poland and Turkey) using truncated current OECD country weights.