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Real Exchange Rate Determinants in the Industrialised Commodity Currency Economies: An error-correction framework

William Robert Speller*

Abstract

Although located at far-flung points of the globe, Australia, Canada, Iceland, New Zealand and Norway have an intrinsic similarity and together represent an anomaly in international macroeconomics; they are the industrialised commodity currency economies. These five nations have advanced and developed while maintaining their traditional dependence on primary resources, thereby exposing the value of their respective currencies to the volatility of global commodity price cycles. There is increasing discourse in these countries regarding the desirability of this feature. This thesis takes a step back from this debate and employs an error-correction framework to investigate whether exogenous shocks to the commodity terms of trade are indeed a fundamental determinant of the long-run equilibrium real exchange rate. I find that the influence of commodity prices on the Australian and New Zealand dollars evidenced in previous studies has continued throughout the 1999-2005 commodity price boom. Conversely, in Canada there appears to have been a fundamental shift in the nature of the relationship during the past decade. In the first study to apply this framework to Iceland and Norway, I find that the model only performs well for Iceland after the float of the króna, and that the Norwegian krone exhibits a non-linear relationship with the price of oil. Overall the message is clear: the real price of the commodity exports of each of these countries continues to be a fundamental determinant of the real exchange rate.

Advisor:	Assistant Professor David Domeij
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Discussants:	Ann-Sofie Stenérus and Andreas Guiance

*80300@student.hhs.se

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1. INTRODUCTION

Ask an Australian coal miner, lugging anthracite out of a pit in rural Western Australia and an Icelander, cod-fishing in the Greenland Sea what they have in common, and you might receive some rather odd looks. In reality, however, the nature and strength of the impact their daily activities have on the economy of their respective nations are much more similar and extensive than either might anticipate. Australia and Iceland, together with Canada, New Zealand and Norway represent an anomaly in international macroeconomics; they are the industrialised "commodity currency" economies.

A commodity currency is generally defined as a currency that exhibits a persistent and strong positive relationship with prices of resource-based commodities (Cashin, Céspedes & Sahay, 2002). A high degree of dependence on commodity exports is typically a feature of developing countries, whose economies have not progressed enough to allow their export base to diversify much beyond what can be dug of out the ground, picked from trees, or caught at sea. However, the five nations which are the focus of this thesis comprise the unique group of industrialised commodity currencies. Despite the advancement of technology and industry within these countries, primary commodities continue to dominate their export horizon owing largely to a wealth of natural resources. Consequently, the value of their respective currencies remains closely linked to cycles and fluctuations in world commodity prices.

There is a wealth of literature and research into the implications and desirability for developing countries to be commodity exporters, starting with the classical works of Prebisch (1950) and Singer (1950). In Australia, Canada, Iceland, New Zealand and Norway, as well, the attractiveness of being a commodity currency and what it implies for the economy, the conduct of monetary policy, and other issues continue to be a source of debate. Pundits in Australia forebode that Australia is at the mercy of the commodity cycle, highlighting the vulnerability of the economy to commodity price shocks (Bartholomeusz, 2005). Central bank forecasting procedures in Canada and Norway heavily focus on the influence of commodity terms of trade. The recent financial mini-crisis in Iceland was in part blamed on the dependence of the króna on world commodity prices. Curiously, the króna's 4.4 percent devaluation against the U.S. dollar on 21 February 2006 was followed by a 6 percent devaluation of the New Zealand dollar against the U.S. dollar the following week. To some in New Zealand, this degree of sensitivity to events in a distant and seemingly unrelated economy gave new meaning to the nation's infamous epithet, 'the shaky isles.'

As commodity prices around the globe reach record highs, and these five economies reap the rewards, the debate rages on. It is ironic that the debate in these nations is most fierce when times are good and economic growth is strong. Average real GDP growth during 2000-05 across the five countries was 3.3 percent, compared to the overall OECD average of 2.4 percent (OECD, 2006). Furthermore, there can be little argument that, historically speaking, these economies have each benefited greatly from an endowment of natural resources, a legacy of scarce and highly sought after goods, the export of which facilitated the prerequisite accumulation of wealth that industrialisation demanded. Nevertheless there is increasing deliberation regarding whether the benefits are outweighed by the negative implications of having a currency whose value is so closely aligned to commodity export prices.

A better understanding of the behaviour of these currencies would benefit economic policy decision makers in the countries themselves. The issue also has implications for developing countries as they advance and liberalise their capital markets (Chen & Rogoff, 2002). Indeed, the Chilean Minister of Finance has claimed recently that Chile intends to follow the 'Australian model' of liberalisation (MacFarlane, 2005). By this statement he endorses a macroeconomic policy model that has the following structural features at its core: a monetary policy regime based on central bank independence and an inflation target; a disciplined fiscal policy which aims at balance or surplus in the medium term; and *a floating exchange rate with a currency viewed as a commodity currency* (MacFarlane, 2005). This notion has been met with scorn by critics in Australia, with claims such as, "Presumably Chile is also content to have its domestic import-competing and non-commodity export industries periodically savaged by the commodity price cycle, the same way farmers are perennially scrambling to recover before the next drought hits, " (Bartholomeusz, 2005).

However, one factor that is often overlooked in these arguments is that both sides of this debate presuppose an understanding of exactly what determines exchange rates. In reality, this has been and remains one of the more notoriously contentious aspects of international macroeconomics. The breakdown of the Bretton-Woods system and subsequent floating of many of the world's major currencies gave rise to an abundance of theories and approaches, seeking to explain which factors determine the value of a currency. Today, perhaps the main consensus regarding the determinants of exchange rates is that there is no consensus.

During the 1970s, research and literature focused on the *monetary approach* to exchange rates. This approach postulates that exchange rate fluctuations are derived from differences in price levels and changes in inflation rates across countries. The crowning theory of the monetary approach is that of Purchasing Power Parity (PPP), which in its most extreme form states that real exchange rates should be constant over time since price differentials are completely offset by changes in the nominal exchange rate. Thus, the price of a basket of goods should be equal in all countries, once the exchange rate has been taken into account. This 'Law of one Price' also applies to financial markets through the notion of Uncovered Interest Parity (UIP).

While this approach had empirical success in explaining the inflationary episodes of the 1970s and when the countries studied had large differences in price levels, it failed regarding countries with more similar inflationary experiences (Lafrance & Van Norden, 1995). In 1983, the seminal work of Meese and Rogoff showed that existing monetary exchange rate models, which appeared to fit well in-sample, could not outperform a naïve random walk in explaining out-of-sample exchange rate movements, thereby debunking PPP in the process. This finding has not been conclusively refuted in the succeeding three decades and has spawned a mass of literature on the failures of PPP and UIP. Meese and Rogoff (1983) also inspired researchers, unwilling to accept the random walk hypothesis, to create better models for the exchange rate.

The two resulting dominant approaches to modelling exchange rates can be loosely categorized as either focusing on *non-monetary factors* or focusing on *exchange market psychology*.

The first approach deems that the failure of monetary models is largely owing to their omission of some important sources of non-monetary shocks that change long-run real exchange rates. It claims that there are economic fundamentals, influencing the real exchange rates that require consideration. Examples of factors and shocks that have been studied are government debt levels, net foreign asset position, productivity differentials (via the Balassa-Samuelson effect) and natural resource discoveries. One further example, which is the focus of this paper, is exogenous changes in the terms of trade. Theoretically, an increase in world prices for a country's exports will result in an appreciation of the real exchange rate by creating a foreign currency surplus and raising national income, and consequently aggregate demand. As commodity prices are mainly determined in world markets and tend to be volatile, they are among the most important external shocks affecting commodity currency economies.

The notion that rising export prices create a real currency appreciation is closely related to an effect commonly dubbed the Dutch Disease, which was introduced by Australian economists Corden and Neary (1982), and was based on a model of a small, open economy with a non-tradable and a tradable sector at its core. In their model, the real exchange rate reflects the nominal exchange rate, adjusted for the relative price of a country's tradable and non-tradable goods. As is the norm in small, open economy models, export prices are treated as exogenous; therefore individual countries cannot influence world prices. Thus, an increase in the world price of a country's exports will appreciate the real exchange rate through two main mechanisms. Firstly, higher export earnings will cause an inflow, and a subsequent surplus, of foreign currency. In the absence of central bank intervention to soak up the excess supply, there is an appreciation of the nominal exchange rate. This in turn results in a real appreciation. Secondly, the export price rises increase domestic income. This income effect increases demand for goods and services in the economy. This will be manifested not only through increased imports but also is likely to cause price rises to eliminate excess demand in the non-tradable sector. Since the prices of goods in the tradable sector are exogenous and determined in the world market, they do not change. The result is again an appreciation in the real exchange rate.

The *exchange market psychology approach* to modelling exchange rates, on the other hand, rests less in economic fundamentals and in fact argues that the failure of monetary models is evidence of the lack of importance of fundamentals in foreign currency markets (Lafrance and Van Norden, 1995). In recent years, this approach has drawn increasingly from the market microstructure literature and focuses on information asymmetries and the dispersal of information in the market (Lyons, 2001).[1] Exchange rates are instead driven by speculation, expectations and self-fulfilling beliefs; if a currency were expected to appreciate, then demand for it increases, thereby creating an appreciation. This kind of argument is often promulgated in the commodity currency economies, where it is perceived that the exchange rate is excessively sensitive to commodity prices, resulting in persistent misalignments and exposing the economy to excessive risk of terms of trade shocks. Furthermore, it is often claimed that foreign exchange markets do not adequately differentiate between the various commodity currencies, and consequently the value of their currencies is dependent on commodities which they do not themselves produce (Cashin, McDermott & Scott, 1999).

Thus both the *non-monetary* and *exchange market psychology* approaches to exchange rate modelling are particularly applicable to the commodity currencies. According to the *non-monetary approach*, a high dependence on commodity exports makes an economy more susceptible to fundamental economic terms of trade shocks. In the *exchange market psychology approach*, this feature makes a currency a prime target for speculation and irrationality in the foreign exchange markets. The focus of this thesis is to provide additional empirical evidence to the debate, in the context of the commodity boom and for the industrialized countries most likely to be affected by it.

The empirical means I use to this end is an error-correction model, following the work of researchers at the Bank of Canada, who have long-maintained that such a model can explain most fluctuations in the Canadian dollar. This framework first developed by Amano and van Norden (1993) included four explanatory variables pertaining to interest rate differentials and commodity terms of trade. Significantly, it was one of the first models to outperform a random walk in out-of-sample forecasts (i.e. it passed the Meese-Rogoff test). The model has been stable over time and has withstood extensive econometric testing. It continues to be an integral element in the Bank of Canada's internal forecasting procedures (Clinton, 2001). Similar models have been subsequently applied to Australia and New Zealand with substantial success (see Gruen and Kortian, 1996 and Djoudad *et al.*, 2001).

This paper applies the Amano and van Norden framework to an expanded data set; a key feature of which is that it includes data covering the recent boom in world commodity prices. The work of Amano and van Norden and other subsequent papers study periods of generally declining world commodity prices, with the exception of sharp spikes from the oil crises of the 1970s. The recent commodity boom is virtually unparalleled, with record prices

1 Lyons (2001) and Sarno and Taylor (2001) provide excellent overviews of market microstructure models.

in a number of commodities including gold, coal and oil. Thus further investigation into the nature of the relationship between commodity prices and exchange rates is particularly topical in the new commodity price environment.

Another major contribution of this paper is that it is the first time, to my knowledge, that this framework has been applied to the economies of Iceland and Norway. These countries share common features with Australia, Canada, and New Zealand; namely all are developed economies, with floating currencies, inflation-targeting exchange rate regimes, and currencies characterised as commodity currencies. Accordingly, I investigate whether error-correction models can be applied successfully to this unique subgroup of macroeconomies.

The results of this study are both impressive and intriguing. In the cases of Australia and New Zealand, I find that the relationships existing in the previous literature have persisted through the commodity boom and appear relatively stable over time. However, this is not the case for Canada, for which I find evidence of a fundamental shift in the nature of the relationships. The well established anomaly of a negative relationship between the Canadian dollar and its energy exports is apparent throughout the 1970s, 1980s and early 1990s. However, the coefficient appears to have reversed its sign during the course of the last decade. This result should be viewed with suspicion, and warrants further investigation, as there seems to be limited intuitive support for such a radical shift.

In the case of Iceland, the sample period spans observations both prior to and after the króna's float in 2001. I find that the model is a poor explanator for the pre-float period, but fits well after 2001. This is a theoretically attractive result as it indicates that the forces determining the real exchange rate equilibrium are strongest when they are not subject to interference from a central bank that explicitly targets the value of the currency. Given the small post-float sample period, however, I cannot draw strong conclusions regarding the reliability of the model for the króna. Contrary to the evidence on Iceland, the model for Norway performs well until the turn of the century; however it is a poor explanator during the recent oil price hike. This seemingly counter-intuitive result supports existing literature which finds a non-linear relationship between the krone and the price of oil. Oil prices tend to exert a stronger influence on the value of the krone during periods of relatively low or declining oil prices, as compared to periods of high or rising prices.

This paper is structured as follows. Section 2 provides background information on the salient features of the commodity currency economies included in this study. Section 3 explains the selection and construction of the variables and data used in the models. Section 4 describes the operation of the error-correction models and explains their linkages to economic theory. Section 5 presents and discusses the results of the models. Section 6 concludes.

2 BACKGROUND ON THE COMMODITY CURRENCIES

2.1 DEFINING THE INDUSTRIALISED COMMODITY CURRENCY ECONOMIES

The term 'commodity currency' has in recent years gained increased popularity among economists and currency traders. A country is generally deemed to have a commodity currency when there exists a persistent and long-term relationship between fluctuations in its real exchange rate and movements in the real price of its commodity, or resource-based, exports (Cashin, Céspedes & Sahay, 2002).[2] It is logical to expect that economies, for which primary commodities comprise a significant portion of total exports, will tend to have currencies that are highly dependent upon the world price of commodities they export.

This feature is generally associated with developing countries which are not sufficiently industrialised to diversify their export bases beyond raw materials and are consequently heavily reliant on primary exports. For example, during the 1990s commodity exports represented 97 percent of Burundi's total exports, 90 percent of Madagascar's, and 88 percent of Zambia's. Furthermore, some developing countries are significantly dependent upon one single exportable commodity. The major export good exceeded 90 percent of commodity export receipts in Dominica (bananas), Ethiopia (coffee), Mauritius (sugar), Niger (uranium), and Zambia (coffee), (Cashin, Céspedes & Sahay, 2002).

In this context, a commodity currency might be regarded as an unfavourable attribute, a characteristic indicating backwardness and under-developed industry. As countries advance and become richer, the focus of the economy tends to shift away from raw materials and towards more technologically advanced processes. However, a handful of developed economies have industrialized and advanced in many areas while maintaining the traditional importance of natural resources to the economy. The prime examples are Australia, Canada, Iceland, New Zealand and Norway. The most significant, recent works on defining the commodity currencies are those of Cashin, Céspedes & Sahay (2002) and Chen & Rogoff (2003), which identify these five nations as the industrialised commodity currencies.[3]

As the term commodity is not consistently interpreted in economic literature, it is useful to employ the framework of the Standard International Trade Classifications (SITC) formulated by the United Nations Statistics Division, in order to define what comprises a primary commodity.

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2 This definition is distinct from the meaning of 'commodity currency' in the international finance literature, in which the term refers to post World War II proposals to establish commodity-reserve currencies (see Graham, 1937).

3 Additional candidates are suggested by other studies. For example Baxter and Kouparitsas (2000) consider Finland, Greece, Ireland and the Netherlands. However, the works of Cashin, Céspedes & Sahay (2002) and Chen & Rogoff (2003), which are the most expansive on the subject to date, do not find the necessary relationship for these countries. Moreover, the adoption of the Euro by these countries implies any analysis of them would be redundant.

The SITC divides all internationally traded merchandise into nine broad categories, composed of various sub-categories. Classification is based primarily on the type of material, the level of processing undertaken and the technology used in production (United Nations Commodity Trade Statistics Database, 2006). This study follows the standard protocol on primary commodities and defines a primary commodity as a good included in SITC codes 0, 1, 2, 3, 4, 6.7, 6.8 and 9.7. A full list of the SITC codes and the classifications used in this paper are provided in Appendix 1.

2.2 COMPOSITION OF EXPORTS

The composition of each country's exports during the period 2000-04 is summarised in *Table 1*.

Table 1: Composition of exports, 2000-04

	Commodity Exports / Commodity Imports	Energy Exports / Energy Imports	Non-energy exports / Non-energy imports	Commodity Exports / Total exports	Agriculture (SITC 0+1) / Commodity exports	Energy (SITC 3) / Commodity exports	Other commodities (SITC 2+4, 67, 68, 97) / Commodity exports
Australia	3.39	2.21	4.32	68.9%	27.1%	29.0%	43.9%
Canada	2.17	2.80	1.83	33.9%	19.1%	43.3%	37.6%
Iceland	2.76	0.03	8.64	87.3%	70.8%	0.4%	28.8%
New Zealand	2.79	0.18	4.46	69.3%	69.6%	2.6%	27.8%
Norway	5.79	26.81	1.31	78.6%	7.8%	81.1%	11.1%

Source: United Nations Commodity Trade Statistics Database (UN Comtrade).

The first column of *Table 1* shows the ratio of each country's commodity exports to its commodity imports. Evidently all five countries have a ratio of greater than 1, indicating that all are net commodity exporters as expected. The next two columns indicate whether the economies are net exporters of both energy and non-energy commodities (refer to Appendix 1 for precise composition of each). Australia, Canada, and Norway are all net exporters of both, although the ratios between the two are more balanced for Canada and Australia. Norway, on the other hand, is only a marginal net exporter of non-energy commodities, while it has an extremely high energy ratio, largely owing to massive oil exports which constitute 64 percent of total merchandise exports during this period. Iceland and New Zealand are both net importers of energy but net exporters of non-energy commodities.

The fourth column describes the relative importance of commodities in each country's total exports. Clearly, Canada has the most diversified export base of the countries studied, owing to its strong manufacturing and chemical industries. Conversely, Iceland and Norway are the most commodity-dependent, primarily in relation to marine products and oil, respectively. Australia and New Zealand exhibit a similar degree of commodity-dependence.

The final three columns divide the composition of each country's commodity exports into agricultural products, energy products and other commodities, the latter primarily consisting of metals and minerals. The commodity exports of Australia and Canada are relatively well spread across the three groups. While Australia is a leading producer of agricultural products such as beef, wheat and wool, it also has extensive metal and mineral resources in the form of gold, iron ore, copper and uranium among others. The relatively high percentage of energy derives from Australia's immense coal resources that make it the world's leading producer. Canada is similarly diversified across commodities as it is also endowed with significant agricultural, energy and metal resources. In contrast to Australia, the driving force behind the agricultural weight is Canada's forestry industry which generates substantial export revenue from lumber and pulp. Crude petroleum and natural gas constitute its energy resources.

New Zealand and Iceland exhibit broadly similar commodity export structures, with agricultural products dominating their export horizons. New Zealand's 12:1 sheep to person ratio has made it the subject of many jokes, particularly from across the Tasman Sea. However, this composition has enabled the nation to become the source of roughly 50 percent of global lamb exports, which combined with wool, beef and dairy products form the heart of the New Zealand economy. In Iceland, fish constitutes over 65 percent of all merchandise exports.[4] Both countries also have substantial metal exports, mainly in the form of aluminium, while their energy resources are negligible.

Norway's dominant three commodity exports are fish, aluminium and oil. The pre-eminence of the latter is evidenced by the fact that oil comprises in excess of 80 percent of commodity exports.

2.3 EXCHANGE RATE REGIMES

In addition to a reliance on commodity exports, another common trait linking these five economies is that monetary policy in all of them is conducted by an inflation-targeting central bank, operating under a floating exchange rate regime. The timing and reasoning

4 Although strictly speaking fish is not an agricultural product, I classify it as such based on its very similar characteristics to agricultural products.

behind the adoption of the present monetary policy regime, however, differs from country to country.

Canada, Australia, and New Zealand all have long histories of floating exchange rate regimes. Canada was one of the first countries to float its currency during the collapse of the Bretton Woods system; the float of the dollar on 31 May 1970 actually preceded Nixon's official closure of the gold window. Neither Australia nor New Zealand was part of the Group of Ten to sign the subsequent Smithsonian agreement, the collapse of which led to a movement to floating exchange rates among the world's major currencies. Through the 1970s and early 1980s, both nations maintained pegged or managed floating systems tied to trade-weighted currency baskets. The Australian and New Zealand dollars were eventually floated on 12 December 1983 and 4 March 1985 respectively, as a part of a broad agenda of economic reform and deregulation in each country, aimed at reinvigorating the then stagnating, domestic economies.

A floating exchange rate is a more recent advent in Norway and Iceland. Norway operated a variety of fixed exchange rates post-Bretton Woods. The last of these was an official peg to the ECU in the early 1990s which was suspended and then abandoned in late 1992, following an international wave of currency speculation. Even more recent is the float of the Icelandic króna on 27 March 2001, which was the culmination of a series of financial deregulations undertaken in the preceding 15 years which radically transformed the Icelandic economy.

It is well-documented that this trend of the floating of exchange rates within the OECD countries post-Bretton Woods is associated with increases in volatility in both nominal and real exchange rates. The five economies studied here are no exception. Since their respective flotation dates, the currencies have been subject to marked and persistent fluctuations that are broadly inconsistent with PPP. It is this realisation that has given rise to the dichotomy between dominant paradigms, seeking to explain these movements – the *non-monetary approach*, focussing on exogenous shocks, and the *exchange market psychology approach*, focussing on investor sentiment and rationality. The primary purpose of this paper is to assess one specific branch of the *non-monetary* approach; I examine whether exogenous shocks to the commodity terms of trade exert an influence on the long-run real exchange rate of the five countries studied.

3 DATA

3.1 PERIOD OF STUDY

In selecting the period of study for each country, my primary concern is to focus on a period during which the value of the currency was allowed to fluctuate without excessive interference from governments or central banks. Ideally, exchange rates should be determined by demand and supply in the foreign exchange markets. When a central bank interferes to buy or sell its currency so as to maintain a predetermined rate, distortions to the true long-run equilibrium value of the currency are created. From time to time such central banks opt, or are essentially forced, to make adjustments to the predetermined exchange rate in response to changes in the underlying demand for the currency; however such changes do not reflect the dynamic adjustment process which I seek to model.

The focus of this paper is to assess whether changes in the prices of a country's commodity exports influence the demand and supply of a country's currency, thereby causing shifts in the long-run equilibrium. Such an effect is difficult to gauge within the context of a central bank's tinkering to negate the impact of market forces. Thus, with this criterion in mind, the following country-specific time periods were chosen for this study, as presented in *Table 2*.

Table 2: Sample periods by country

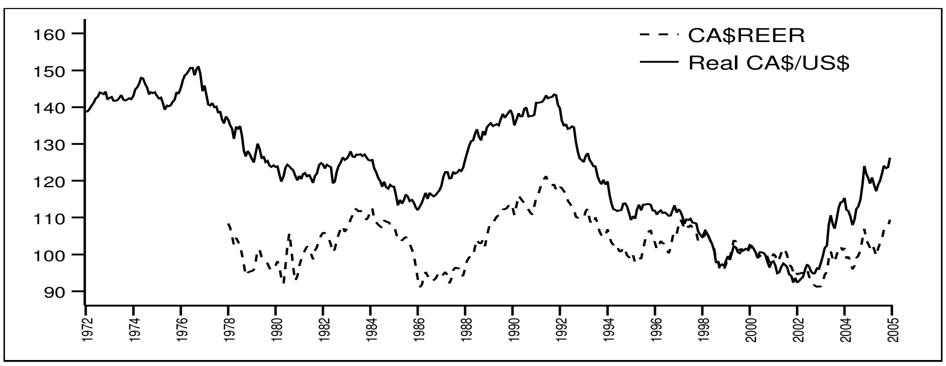
Country	Sample period
Australia	1 January 1985 – 31 December 2005
Canada	1 January 1972 – 31 December 2005
Iceland	1 January 1991 – 31 December 2005
New Zealand	1 January 1987 – 31 December 2005
Norway	1 January 1993 – 31 December 2005

For Australia, Canada, New Zealand and Norway a small post-float lag is applied to allow the currency a chance to 'normalise' and adjust to the new regime. Unfortunately, the very recent floatation of the Icelandic króna implies that a data set of only post-float observations limits the power of the model and testing procedures. Consequently, it was necessary to extend the sample period to include pre-float observations. From 1974 to 1989 the króna was managed with varying degrees of flexibility and restrictiveness, was subject to changes to the basket of currencies to which it was tied, and had no fewer the 25 devaluations (Guðmundsson et al, 2000). The 1990s, however, marked a change in Icelandic economic policy to shift the role of the exchange rate to a monetary anchor from that of a tool of adjustment (Guðmundsson et al, 2000). Therefore, in the decade prior to the float, the króna can be characterised as having been less influenced by changes in the monetary framework. Thus, since the data set must be extended, the best choice is to extend it to the period in which the exchange rate regime was relatively consistent; hence the sample period for Iceland begins at the start of 1991.

3.2 REAL EXCHANGE RATES

Figure 1 to *Figure 5* illustrate the behaviour of the real exchange rates of the economies during the relevant period of study for each. The real effective exchange rate (REER) series are the trade-weighted averagea of bilateral exchange rates with trading partner currencies, adjusted for differences between domestic prices and foreign prices (also on a trade weighted basis).[5] The bilateral real exchange rates with the U.S. dollar are my own construction based on nominal exchange rates and consumer price indices from IMF IFS database.[6] All exchange rates are expressed as the number of foreign currency units per home currency unit, so that increases in either effective or bilateral exchange rates represent an appreciation of the domestic currency.[7]

Figure 1: Canadian real exchange rates – bilateral US$ and real effective (2000=100).



Note: Real effective exchange rate data is not available prior to 1978.

5 The REER index series are taken from the International Monetary Fund's (IMF) International Financial Statistics (IFS) database, which calculates a seasonally-adjusted REER as:

$$REER_i = \frac{P_i N_i}{\exp\left\{\sum_{i=1}^{n} \left[W_{ij} \ln\left(P_j N_j\right)\right]\right\}}$$

in which i is the country in question, j is an index of i's trading partners, W_{ij} is the weight of trade between i and j. P_i and P_j are the CPI in country i and j respectively, and N_i and N_j are the nominal exchange rates of the respective countries in U.S. dollars.

6 The standard formulation of the real exchange rate is used. That is,

$$rer_{i,t} = e_{i,t} \times \frac{p_t}{p^*_{i,t}},$$

in which p_i is the price level in the home country, $p^*_{i,t}$ the foreign price level (i.e. the U.S. price level), and $e_{i,t}$ is the nominal home country to U.S. dollar exchange rate, expressed as U.S. dollar per home currency unit (Reserve Bank of Australia, 2001).

7 Standard market quotations for the Australian and New Zealand dollars are usually expressed as the number of US dollars per home currency unit (denoted AUD/USD), whereas the Canadian dollar, Norwegian krone and Icelandic króna are expressed as home currency unit per US dollar (denoted, for example USD/CAD).

Figure 2: Australian real exchange rates – bilateral US$ and real effective (2000=100).

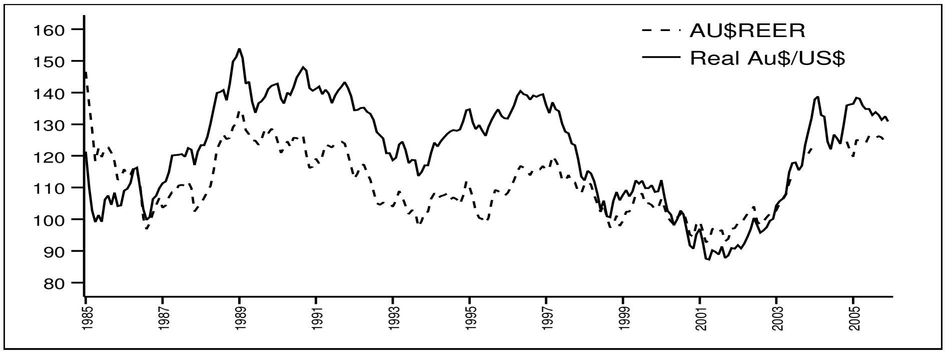


Figure 3: New Zealand real exchange rates – bilateral US$ and real effective (2000=100).

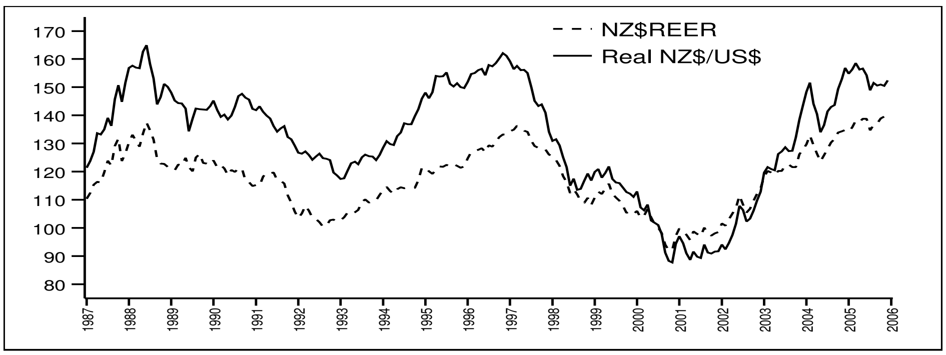


Figure 4: Iceland real exchange rates – bilateral US$ and real effective (2000=100).

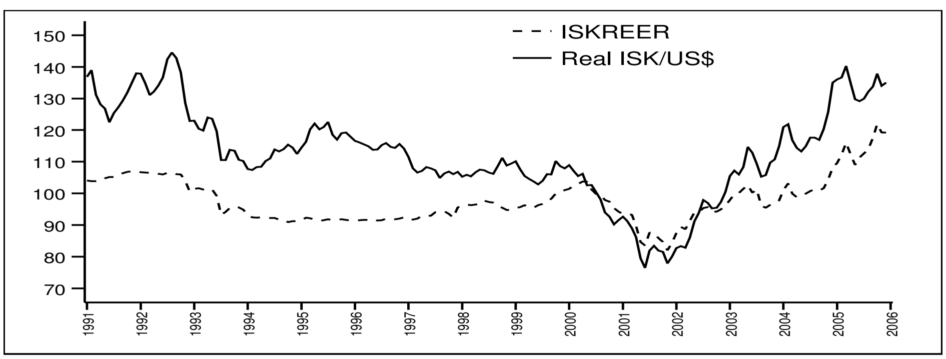
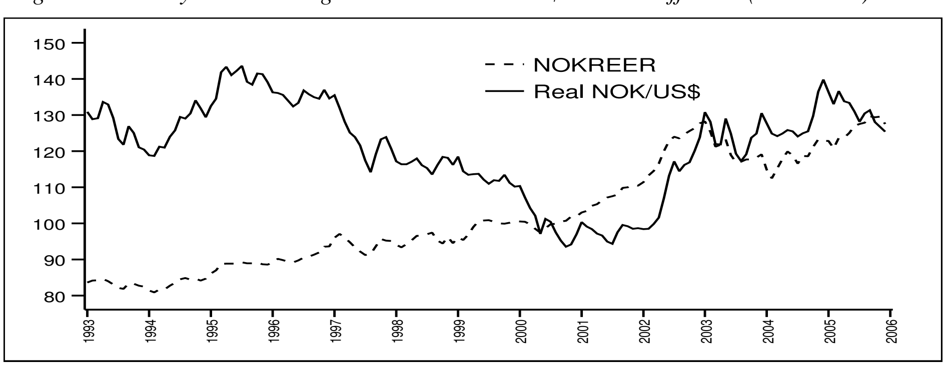


Figure 5: Norway real exchange rates – bilateral US$ and real effective (2000=100).



A cursory glance indicates that the Australian, Canadian, and New Zealand currencies track a similar path. All were relatively strong throughout the 1980s and first half of the 1990s, before depreciating for a period to a trough around 2001. Since 2001 all have experienced quite rapid appreciations. Also of note is the high degree of co-movement between the real effective and real bilateral U.S. dollar exchange rates that is evident for each of these countries. This is a particularly unsurprising and well-documented feature of the Canadian dollar, given that in excess of 85 percent of Canadian exports are U.S. bound. Furthermore, although Australia and New Zealand have lower proportions of trade with the U.S. (7 percent and 15 percent, respectively) a large percentage of their exports go to Asian nations that maintain some form of currency peg to the U.S. dollar; therefore they also have an inherent relationship with the U.S. dollar.

It is perhaps more surprising that the chart for the Icelandic króna also exhibits close co-movement between the two real exchange rates. Prior to 2001, the effective exchange rate was fairly constant, a feature which is largely a product of the limited flexibility or managed float exchange rate regime *de jure*. The bilateral exchange rate exhibits slightly more variation, and is perhaps a better measure of international competitiveness; yet it is still quite stable. Since the floating of the króna, however, there has been a sharp appreciation in line with the behaviour of the Canadian, Australian, and New Zealand dollars. The close post-float association between the Icelandic bilateral and trade-weighted exchange rates is somewhat surprising as the U.S. share of Iceland's exports (9 percent) is dwarfed by the share going to EMU countries (48 percent) and the United Kingdom (18 percent). This could be viewed as a reflection of the fact that a significant amount of international trade and finance transactions are denominated in U.S. dollars, even when none of the parties involved is domiciled in the U.S.A. (Djoudad *et al.,* 2001).

The chart of the Norwegian krone stands apart from the rest. There appears to be little common pattern between the effective and bilateral exchange rates since the currency's float in late 1992, with the exception of post-2001 when the two track a more similar path. The real krone bilateral U.S dollar rate plots a similar course to the bilateral rates in the other countries studied. This could indicate that the bilateral rate is being dominated by factors impacting the United States' economy rather than the Norwegian economy. Given that the proportion of Norwegian exports going to EMU countries (42.6 percent), the United Kingdom (19.3 percent), and other Nordic countries (12 percent) all exceed that going to the United States (9.3 percent), the real effective exchange rate is probably a better measure of Norway's international competitiveness than the bilateral U.S. dollar rate.

In selecting an exchange rate variable, the real effective exchange rate may be theoretically more appealing as it provides a measure of a country's international competitiveness in relation to all its trading partners, whereas a bilateral measure may be biased depending on the choice of base currency. However, studies of the Australian and New Zealand dollar have found that trade-weighted indices tend to underestimate the importance of United States, and provide a less reliable measure of each country's competitive position (Brook 1994; Karfakis & Phipps, 1999). A trade-weighted index tends to create bias by under-weighting the level of trade conducted in U.S. dollars, because such trade is over and above direct trade with the U.S.A. To avoid such pitfalls, I use the bilateral exchange rate in preference of the effective exchange rate whenever it makes sense to do so, specifically whenever the statistical properties of the two rates are similar enough that there should not be a large effect on the results. Accordingly, the bilateral real exchange rate is used for all countries except for Norway which, as discussed above, has exchange rates exhibiting a significant degree of divergence from one another. As such, the IMF's Norwegian real effective exchange rate is used in lieu of my constructed real bilateral U.S. dollar rate.

3.3 Real commodity prices

Previous empirical studies (see Baxter and Kouparitsas, 2000 and Kouparitsas, 1997) have shown that the terms of trade for commodity exporters is basically derived from the relative price of commodity exports and the domestic price of consumer goods. The price of commodity imports has little bearing owing to the conformity of import share in most countries devoted to manufactured goods (around 65 percent), non-fuel goods (20 percent) and fuels (15 percent), (Kouparitsas, 1997). Therefore, when assessing the impact of commodity prices on an exchange rate, the primary concern is the price a country receives for its exports. For example, crude petroleum accounts for close to 80 percent of Norway's commodity exports; yet it imports a much wider array of commodities; thus one would expect movements in the commodity terms of trade for Norway to be dominated by fluctuations in the world price of petroleum. Variations in the commodity terms of trade arise because a country exports one basket of goods, and imports a different basket of goods. For the commodity currency economies, the basket of exports is far more specialised than the basket of imports. Hence, it is commodity exports that primarily determine the commodity terms of trade and which are of interest in this study.

Therefore, to explain fluctuations in the real exchange rate for a particular country, all real commodity price variables should reflect the world prices of that country's commodity exports. In addition, it is important to use separate variables for energy commodity prices and non-energy commodity prices, rather than a composite variable which includes all commodity types. Amano and van Norden (1993) find that energy prices have a very different impact on the Canadian dollar as compared to non-energy prices. Thus separate variables are required for Canada, Australia and Norway as these countries are net exporters of both energy and non-energy commodities (see *Table 1)*. Conversely, only a non-energy commodity price variable is required for both New Zealand and Iceland, owing to the fact that their energy exports are insignificant.

The Bank of Canada Commodity Price Index (BCPI), produced by Bank of Canada and published by Statistics Canada, is a monthly fixed-weight index of the spot price of Canada's 23 key commodity exports. Weights for the index are determined on the basis of the value of Canadian production of each commodity during the period 1988-99. The BCPI also provides sub-indexes for energy and non-energy commodity prices, which are ideal for the purposes of this study.

For New Zealand, the non-energy commodity terms of trade index is the Australia and New Zealand Banking Group Limited (ANZ) commodity price index, US dollar series. For Australia, Iceland, and Norway no appropriate index was readily available.[8] Hence I construct my own commodity export price indices – both energy and non-energy indices for Australia and Norway and only an energy index for Iceland.

My construction of country-specific indices of commodity export prices is in line with the methodology of Deaton and Miller (1996), Dehn (2000), and Cashin, Céspedes & Sahay (2002). A Laspeyres fixed-weight commodity index is created as the geometrically-weighted index of the nominal prices of each country's significant commodity exports, in which the nominal index is determined by,

$$NIndex = \exp\left\{\sum_{k=1}^{K}(W_k \cdot P_k)\right\} \quad where \quad W_k = \frac{(P_{jk}Q_{jk})}{(\sum_k P_{jk}Q_{jk})}$$

P_k is the index of the U.S. dollar world price of commodity *k*; W_k is the individual commodity weight, calculated as the value of exports of commodity *k* and divided by the total value of all *K* commodities, for the constant base period *j* (2000-04); and Q_k is the quantity of exports of commodity *k*. Data on the quantity are sourced from UN COMTRADE, while the individual commodity price indices are taken from the IMF's IFS database and Thomson DataStream. For Australia and Norway, separate indices have been constructed for energy commodities and non-energy commodities. Accordingly, the export value of energy commodity *k* is divided by the total value of all *K* energy commodities to determine *k*'s weight in the energy index. The non-energy index is constructed in a parallel way. All nominal indices are then deflated, using U.S. CPI to create the real commodity price indices. A more detailed explanation of the method used to construct the indices is provided in Appendix 2.

A key motivation for using a Laspeyres index is that commodity weights are held fixed over time. Thus volume effects of changes in commodity export prices are removed, so that price rather than quantity movements drive the index. Furthermore, the fact the these fixed weights are applied to world prices, as opposed to each country's export price, ensures the commodity prices are exogenous as world prices generally are not affected by the behaviour of individual countries.

As stated in the introduction, in probably the most significant work on commodity currencies to date, IMF researchers Cashin, Céspedes and Sahay (2002) construct similar

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8 Data is available for The Reserve Bank of Australia's Index of Commodity Prices. However, this index includes coal and natural gas but excludes petroleum. Therefore, the data does not clearly distinguish between energy and non-energy commodity prices as required for this study.

indices and examine their relationship to real exchange rates in 58 commodity-exporting economies. My national commodity price indices differ from those of Cashin, Céspedes and Sahay (2002) in a number of respects. Firstly, my data set is updated, and therefore calculates index values until the end of 2005. This is significant as it now facilitates the analysis of commodity prices during the recent boom. Secondly, since the publication of Cashin, Céspedes and Sahay (2002), the IMF has increased the number of commodities on which it publishes data from forty-seven to sixty-three, which helps create a more accurate index. Moreover, data for a number of significant commodities not available through IFS were collected from other sources (see Appendix 2 for further details). Thirdly, the base period for weighting of individual commodities is 2000-2004, as opposed to 1982-1990 in Cashin Céspedes and Sahay (2002).[9] Fourthly, for Australia and Norway I create separate indices for energy and non-energy commodities as previous evidence from Canada suggests the two categories may have different relationships with the real exchange rate.

The final composition of each index is presented in Appendix 3. *Figures 6-10* illustrate the movements in each country's indices over the relevant sample period.

Figure 6: Australian commodity price indices (2000=100).

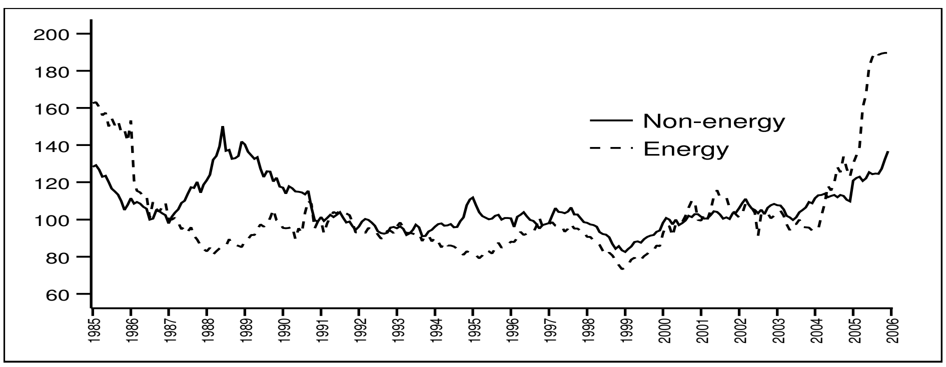
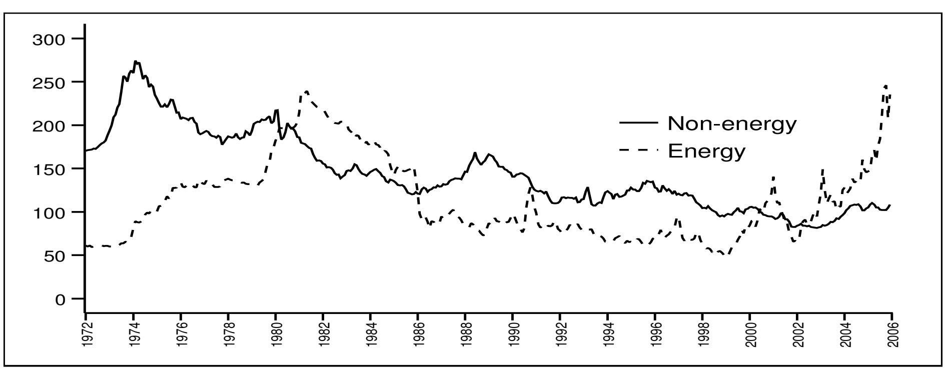


Figure 7: Canadian commodity price indices (2000=100).



9 However, preliminary testing revealed that the indices were not sensitive to changes in the base period.

Figure 8: Icelandic commodity price index (2000=100).

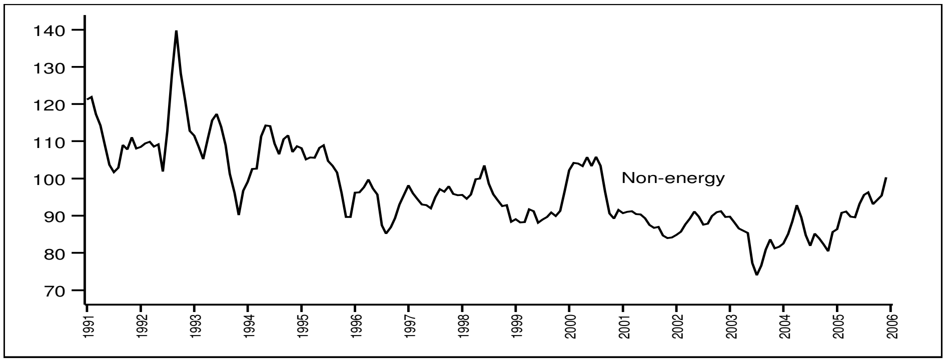


Figure 9: New Zealand commodity price index (Indexed 2000=100).

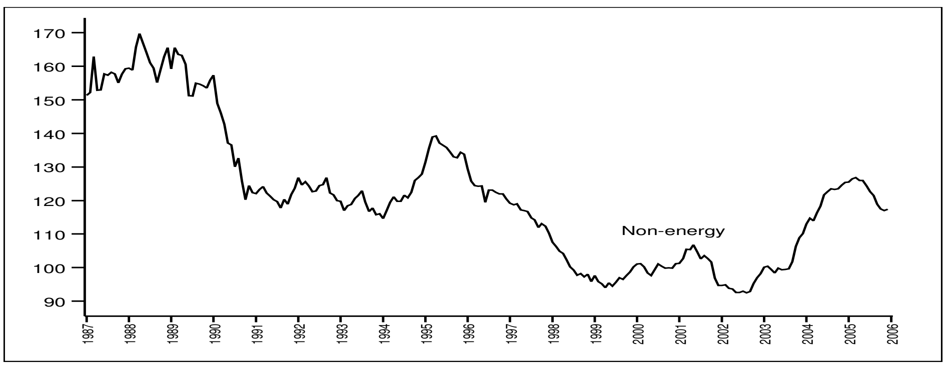
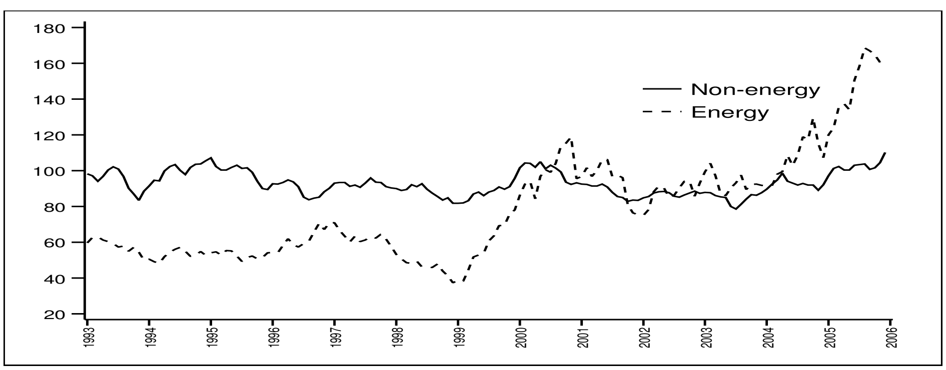


Figure 10: Norwegian commodity price indices (Indexed 2000=100).



These figures provide insight into some of the broad trends in the global commodity cycles in recent years. Most notably, all of the energy indices exhibit sharp increases since the turn of the century – a reflection of the well-documented latest bout of high oil prices. The spike is sharpest for Norway, given its chief reliance on crude petroleum, compared to Canada and Australia that have large coal and natural gas components, for which price rises in recent years have not been as prodigious.

The non-energy indices for Australia and New Zealand track similar paths which are broadly in line with the real exchange rate trends described above. They all experience gradual declines over the course of the 1980s and 1990s before climbing at the turn of the century. The Canadian non-energy index exhibits similar properties, but has missed out on the turn around. One possible reason is that the price increases in metal and agricultural products that have created rises in the indices for Australia and New Zealand may have been counteracted by declining prices for pulp and paper, which form a large proportion of the Canadian index.

The non-energy indices for Iceland and Norway appear much more stable over time, particularly in the case of Norway. This observation, however, masks the fact that increases in the price of aluminium, which constitutes 31.7 percent of Norway's index and 22.2 percent of Iceland's, has to a large extent been balanced by a general decline in the price of fish, which comprises 38.9 percent of Norway's non-energy index and 58.1 percent of Iceland's.

Table 2 provides an illustration of the behaviour of a commodity currency. It provides correlations between each country's real exchange rate, at time t=0, and various lags and leads of its commodity price indices. The most striking results are the high correlations between the Norway's krone and its energy price index, which correspond with the widely held notion that the krone is heavily tied to world oil prices. Consistently high correlations are also observed in relation to non-energy indices of Australia, Canada and New Zealand.

Table 2: Correlations between real commodity price indices and real exchange rates

	Lag or lead of real commodity price index						
	t - 12	***t - 3***	***t - 1***	***t=0***	***t +1***	***t +3***	***t +12***
Australia– Non-energy	0.685**	0.652**	0.663**	0.652**	0.605**	0.525**	0.100
Australia– Energy	-0.215**	-0.136**	-0.106*	-0.179*	-0.065	-0.030	-0.012
Canada– Non-energy	0.731**	0.749**	0.751**	0.752**	0.753**	0.753**	0.742**
Canada– Energy	0.104**	0.106**	0.102**	0.100**	0.100**	0.100**	0.107**
Iceland– Non-energy	0.134	0.352**	0.439**	0.487**	0.514**	0.531**	0.600**
New Zealand– Non-energy	0.601**	0.645**	0.647**	0.647**	0.644**	0.640**	0.553**
Norway- Non-energy	-0.426**	-0.259**	-0.214**	-0.182*	-0.185*	-0.188*	-0.185*
Norway- Energy	0.804**	0.802**	0.808**	0.809**	0.806**	0.798**	0.777**

*Note: **indicates correlations are significant at the 1% level; * indicates significance at the 5% level.*

According to the general theory in this paper, one should expect positive and significant correlations between each country's real exchange rate and its respective commodity price indices. The nature of commodity currencies is that increases in the world price of commodity exports result in an appreciation of the real exchange rate. However, as previously mentioned, existing empirical work suggests that energy prices have a negative impact on the Canadian and Australian dollars (Amano & van Norden, 1993; Djoudad *et al.*, 2001). This previous evidence is not substantiated by the data here. The correlations for the Canadian energy index are positive and low throughout the entire lag-lead span. While there is more convincing evidence of this feature for Australia, as the values are negative, they are nonetheless low and not significant for any of the lead periods. Surprisingly, the Norwegian krone has persistently low correlations with the Norwegian non-energy index. This index is dominated by fish products and aluminium. It is difficult to rationalise why an increase in the price of either of these goods should be associated with depreciations in the Norwegian real exchange rate; however, the correlations can be evidence that the phenomenon observed in previous studies of Australia and Canada is also prevalent in Norway.

Also of noteworthiness is the tendency for Icelandic correlations to increase over time. The correlation between the real exchange rate at t=0 is strongest with the real commodity price index at t+12 and is weaker for the lagged commodity prices. This perhaps indicates that, counter to the assumptions in this paper, the real exchange rate determines the price of commodities, rather than vice versa.

4 ERROR-CORRECTION MODELS

4.1 REVIEW OF THE THEORETICAL MOTIVATION FOR THE MODEL

The theoretical motivation for the error-correction models applied in this paper derives from Meese and Rogoff (1988), who use real versions of the models first proposed by Dornbusch (1976), Frankel (1979) and Hooper and Morton (1982). There are two salient features of these models which are relevant to the framework here: firstly, after temporary shocks, the real exchange rate moves back to some long-run equilibrium at a constant rate; secondly, UIP holds.

Therefore, the first feature states that:

(1) $$\Delta RFX_t = \alpha(RFX_{t-1} - RFX^*_{t-1})$$

in which ΔRFX_t is the change in real exchange rate between period t-1 and period t; RFX_{t-1} is the actual real exchange rate at t-1; RFX^*_{t-1} is the long-run equilibrium real exchange rate at t-1; and α is the speed of adjustment parameter. In theory $-1 < \alpha < 0$, since when the real exchange rate at t-1 is above its equilibrium, there should be an adjusting depreciation (or negative ΔRFX_t).

Following the work of Blundell-Wignall and Gregory (1990), it is assumed that in the small open macroeconomies of the commodity currency economies, the long run equilibrium real exchange rate is a function of the non-energy and energy commodity terms of trade. Therefore,

(2) $$RFX^*_{t-1} = \beta_0 + \beta_1 \cdot NONENG_{t-1} + \beta_2 \cdot ENG_{t-1}$$

in which $NONENG_{t-1}$ refers to the non-energy terms of trade and ENG_{t-1} represents the energy terms of trade. According to the previously explained theory, the parameters β_1 and β_2 should be positive, as increases in the commodity terms of trade lead to appreciations in the real exchange rate. An increase in the world price of a country's commodity exports has a direct effect on the exchange rate as more foreign currency is required to purchase a given amount of goods. The shift in supply of foreign currency leads to an appreciation of the nominal exchange rate. Furthermore, domestic income increases, causing inflation in the non-tradable sector. Since the real exchange rate is determined by relative prices in the tradable and non-tradable sectors, and the tradable sector's prices are determined exogenously, domestic inflation also causes a real exchange rate appreciation.

The above framework is focussed upon the long run response of the exchange rate. However, in modelling changes in the exchange rate, sufficient consideration must also be given to its short-run dynamics. Accordingly, the second assumption gleaned from the aforementioned models is that UIP holds. That is, the interest rate differential is a reflection of the real exchange rate's deviation from long run equilibrium (Meese & Rogoff, 1988). Thus,

(3) $$\Delta RFX_t = i_{t-1}^h - i_{t-1}^*$$

in which i_{t-1}^h denotes domestic interest rate in t-1 and i_{t-1}^* is the foreign interest rate in t-1.[10] According to UIP, the change in the real exchange rate should be equal to the interest rate differential between the domestic and foreign country. Each percentage increase in the interest rate differential should be matched by one percent of expected appreciation.

In this framework, it is assumed that the real exchange rate and the equilibrium real exchange rate (and hence the terms of trade) are non-stationary, whereas the interest rate differential is stationary. Thus, while the terms of trade have long-run impacts on the real exchange rate, interest rate differentials only have a short-run or transitory effect. This assumption is formally tested in section 4.3.

A final precondition for the error-correction model is that the terms of trade must be exogenous; a standard assumption when analysing small, open economies; that is, these economies are price-takers on the world market and cannot impact world supply and demand. The implication of this supposition is that real commodity prices cause real exchange rates but not vice versa. The world price of a given commodity is not impacted by the change in the value of any one country's currency, nor is any country able to manipulate the world price of a given commodity. In this regard, an advantage of using world commodity prices in the construction of real exchange rate variables is that they should not be affected by the actions of individual countries. Even when a country may have significant market power regarding a particular commodity – such as lamb for New Zealand, or nickel for Australia – all of the countries are relatively small in terms of the wider global commodity market. Deaton and Miller (2000) find that even in cases in which a country demonstrates excessive market power, instances of deliberate and successful market manipulation are rare. Furthermore, the degree of substitutability among commodities implicitly lessens any such market power (Chen & Rogoff, 2002), further implying that exogeneity of commodity prices is a reasonable assumption to make.

10 All interest rates used in this paper are nominal rates. In principal the use of real interest rates may be preferable. However, Lafrance and van Norden (1995) find that use of real interest rates considerably reduces the significance of the interest rate variable in similar models, owing to a lack of a good estimate of inflation expectations needed to deflate the nominal rate.

4.2 THE GENERAL ERROR-CORRECTION MODEL

By combining the relationships outlined in the preceding section, changes in the real exchange rate can be modelled using an error-correction framework. The final general model used in this paper is shown in *equation (4).*

(4)
$$\Delta RFX_t = \alpha\left(RFX_{t-1} - \beta_0 - \beta_1 \cdot NONENG_{t-1} - \beta_2 \cdot ENG_{t-1}\right) + \varphi_1 \Delta RFX_{t-1} + \varphi_2 SIDIFF_{t-1} + \varphi_3 LIDIFF_{t-1} + \varepsilon_t$$

The variables included in *equation (4)* are described in *Table 3.*

Table 3: Description of variables included in the general error-correction model

Variable	Description
ΔRFX_t	natural logarithm of the change in real exchange rate from period t-1 to period t
$NONENG_{t-1}$	natural logarithm of the real non-energy price index in period t-1
ENG_{t-1}	natural logarithm real energy price index in period t-1.[11]
ΔRFX_{t-1}	natural logarithm of the change in real exchange rate from period t-2 to period t-1
$SIDIFF_{t-1}$	short term interest rate differential, defined as the difference between the home country (h) and United States (US) short term rates (s) in period t-1 (i.e. $i_s^h - i_s^{us}$).
$LIDIFF_{t-1}$	long term interest rate differential, defined as the difference between the home country (h) and United States (US) long term rates (l) in period t-1 (i.e. $i_l^h - i_l^{us}$).[12]

The essence of the error-correction model is that it combines a long run equilibrium relationship with a short run adjustment process. The error-correction models presented here have three key explanatory components: an error correction term, an adjustment parameter, and short-run or transitory factors.

1. The error-correction term $\left(RFX_{t-1} - \beta_0 - \beta_1 \cdot NONENG_{t-1} - \beta_2 \cdot ENG_{t-1}\right)$

Models of a small open macroeconomy imply that the long run equilibrium value of the real exchange rate is a function of real commodity prices. That is,

(5)
$$RFX_t = \beta_0 + \beta_1 \cdot NONENG_t + \beta_2 \cdot ENG_t$$

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11 The energy terms of trade variable is omitted for New Zealand and Iceland because neither economy is a significant exporter of energy commodities (see Section 2).

12 Different currencies tend to be sensitive to different market interest rates. A short-run interest rate is included in all models. The choice of whether or not to include a long-run interest rate differential was made on the basis of preliminary empirical testing, the results of which can be obtained from me upon request.

According to the theory outlined above, *equation (5)* should hold in equilibrium. In the short run, however, there may be disequilibrium. The term in the parentheses in *equation (4)* represents this disequilibrium and is referred to as the error-correction term. It is the *difference between the previous period's real exchange rate and its estimated long-run equilibrium value.*

The error-correction model is estimated using a two-step procedure (Engle and Granger, 1987). Firstly, *equation (5)* is estimated. Secondly, the residuals from this regression enter *equation (4)* as the error-correction term. β_1 and β_2 are the OLS parameters for the non-energy and energy price indices respectively. According to theory both should be positive. However, Amano and van Norden (1993) find that the sign on the coefficient for the Canadian energy terms of trade is negative. This intriguing result, which has been confirmed and found to exist for Australia as well by Djoudad *et al*. (2001) is discussed later. Given that a negative correlation was found between the Norwegian real exchange rate and non-energy indices, one might also expect a negative coefficient here.

2. The adjustment parameter (α)

α is the adjustment parameter, which reflects the speed of adjustment towards the equilibrium. Theoretically, it is anticipated that the adjustment parameter should be negative. Thus, if the actual real exchange rate in period t-1 is above its equilibrium level (i.e. the error-correction term is positive), then the real exchange rate during period t should depreciate to correct the disequilibrium. The closer the value of this parameter is to -1, the faster the adjustment toward equilibrium. Previous research has found that the value of α is typically around -0.1 to -0.25, indicating a relatively slow speed of adjustment.

3. Short-run or transitory factors (ΔRFX_{t-1}, $SIDIFF_{t-1}$, and $LIDIFF_{t-1}$)

The interest rate differential variables in t-1 and the change in real exchange rates from t-2 to t-1 are included to reflect short-run dynamics of exchange rate movements. These factors are transitory in nature and should not impact the long run equilibrium exchange rate; hence they enter *equation (4)* separately from the error-correction term.

To summarise, the essence of the error-correction models used here is that the change in real exchange rate during period t is a function of: the level of disequilibrium in period t-1; the speed of adjustment towards the long-run equilibrium; and other transitory factors.

4.3 STATIONARITY AND COINTEGRATION

The concept of the error-correction term is closely linked to that of cointegration, which was first espoused by Engle and Granger (1987). They discovered that it is possible for a linear combination of integrated variables to be stationary. Furthermore, the Granger representation theorem states that for any set of I(1) variables, error-correction and cointegration are equivalent representations (Engle and Granger, 1987). When two variables are cointegrated then there exists a long-term equilibrium relationship between them. In the short run, however, there may be disequilibrium. Therefore the error term in the cointegrating regression can be treated as the "equilibrium error". The error-correction model is used to model this disequilibrium and the speed of adjustment toward equilibrium.

Accordingly, the model above assumes that the real exchange rate and the real commodity terms of trade variables for each country not only follow some stochastic trend, but also that they follow the same stochastic trend. Thus, the two series will not drift too far apart in the long run; the residuals from the cointegrated equilibrium relationship are stationary. Since the impact of interest rates is assumed to be transitory, testing should reveal that they are stationary over time.

Thus, in order to use the error-correction model above one must first prove that the real exchange rate and real commodity indices are co-integrated. Moreover, for variables to be co-integrated they must first each be individually integrated. Therefore I performed Augmented Dickey-Fuller (ADF)[13] tests for stationarity and Engle-Granger Augmented Dickey-Fuller (EG-ADF)[14] tests to check for cointegration. The results of these are presented in Appendix 3.

The stationarity tests for the real exchange rate variables all fail to reject the hypothesis that the series contains a unit root. As such, the exchange rates are well characterised by I(1) processes, and are consequently non-stationary. The standard conclusion drawn from this is that PPP does not hold in the long term (Amano and van Norden, 1995). According to PPP, the real exchange rate should be constant over time as price differentials are reflected in and counteracted by changes in the nominal exchange rate. A more significant implication of real exchange rates that are I(1), in terms of the error-correction model, is that they imply that the real exchange rate should, in the long-run, be determined by other I(1) variables.

The tests for stationarity in the explanatory variables also support expectations. That is, the commodity price variables also appear to be non-stationary and exhibit a stochastic trend. Tests of the interest rate differential variables, however, all reject the presence of a unit root

13 The ADF test is known to have a low power against persistent alternatives. That is, it tends to favour a failure to reject the null hypthesis of nonstationarity, if the data does not span a sufficient length of time. In such instances, more elaborate testing procedures such as that proposed by Kwaiatkowski, Phillips, Schmidt and Shin (1992), which have stationarity as the null hypothesis, are often conducted. However, given the complexity of this test and the fact that previous studies have tended to find that ultimate conclusion drawn from it typically corresponds to that of the ADF test, I deem that the ADF test is sufficient for the purposes of this paper.

14 A limitation to the EG-ADF procedure arises when there are more than two variables in the cointegrating system, as is the case with Australia, Canada and Norway. In particular, the danger is that the energy and non-energy indices are cointegrated but unrelated to the real exchange rate. This problem can be overcome by the systems approach of Johansen (1988) and Johansen and Juselius (1990), which can determine the number of cointegrating relationships in the system. These tests are much more elaborate and require specialised software and thus are beyond the scope of this paper. Nonetheless, previous studies for Australia, New Zealand and Canada, that have included both energy and non-energy terms of trade variables, have found each terms of trade variable to be cointegrated with the real exchange rate, but not cointegrated with each other. As such, it is reasonable to assume that this is also the case in my data.

and consequently these variables are stationary. This adheres to the theory that their effect on the real exchange rate is only transitory.

The evidence for cointegration between each country's real exchange rate and its commodity price indices is weaker. The evidence for Australia is strongest with the null hypothesis of no cointegration rejected at the 1 percent level of significance. The tests for Canada and New Zealand reject the null hypothesis at the 5 percent level whereas the tests for Iceland and Norway are only able to reject the hypothesis at the 10 percent level. Nonetheless, there is sufficient evidence of cointegration to proceed with estimation of the error-correction models; the results of which are presented in the following section.

5. RESULTS

5.1 RESULTS FROM THE ERROR-CORRECTION MODELS

The results for the Australian model (*Table 5.1)* show that for the full sample period of 1985-2005, all coefficients are significant and of expected sign. The anticipated anomaly of a negative coefficient for the real energy terms of trade found by Djoudad *et al*. (2001) is also present here. Although Australia is a net energy exporter overall, it is a net importer of oil; a product which tends to be a strong driver of the energy commodity price variables owing to its volatile nature. In this regard, the negative coefficient can perhaps also be attributed to the particular method that I use to construct the commodity prices indices. I do not make an individual assessment on whether a country is a net importer or exporter of each individual commodity. Instead I assess whether the country is a net energy exporter overall and, when it is, I construct an energy index as the weighted average of *all* its energy export products, regardless of whether the country is a net exporter of each individual product. Consequently, oil has a 35% weighting in Australia's energy index despite its being a significant net importer of oil. Within this context, the negative coefficient is not surprising. Higher energy prices raise the value of energy exports; however such gains are more than offset by extra costs for Australia's other industries (Djoudad *et al*., 2001).

Table 5.1: Australia's error-correction model estimation results

Period	**Jan 1985 - Dec 2005**		**Jan 1985 – Dec 1995**		**Jan 1996 – Dec 2005**	
Variable	***Coefficient***	***p-value***	***Coefficient***	***p-value***	***Coefficient***	***p-value***
Adjustment parameter (α)	- 0.178	0.00	- 0.259	0.00	- 0.231	0.00
Constant (β_0)	- 0.004	0.00	- 0.010	0.00	- 0.010	0.02
Real Non-energy index (β_1)	0.477	0.00	0.300	0.00	0.629	0.00
Real Energy index (β_2)	- 0.318	0.00	- 0.604	0.00	- 0.311	0.09
Short term interest differential (φ_2)	0.258	0.02	0.432	0.01	0.658	0.02
Long term interest differential (φ_3)	0.134	0.03	0.424	0.02	0.401	0.14
Lagged change in Rfx (φ_1)	0.264	0.00	0.277	0.00	0.260	0.00
R-squared	0.171		0.177		0.153	

The parameters are not particularly stable over time; yet they remain significant, indicating changes in the relationship over time. Noticeably, the non-energy index has a greater impact in the period 1995-2005 than in the period 1985-1995 while the reverse is true for the energy index. Changes in the coefficients and significance of interest rates suggest that the nature of the short-run dynamics also depends on the time period being studied.

The model also fits reasonably well for Canada (see *Table 5.2)*, in line with previous studies. However, there is one striking feature of the results which, to my knowledge, have not previously been uncovered. The energy index coefficient for the period 1972-1991 is negative in accordance with previous studies which have studied similar time frames. However, in this study this parameter is positive and significant for the period 1992-2005. When testing for the entire sample period at once, the coefficient is insignificant. This suggests there has been a fundamental shift in the impact of energy prices on the Canadian dollar. The previous, negative impact is generally explained by similar reasoning to that above for Australia. Although Canada is a net energy exporter, its extensive manufacturing base as well as its harsh climate imply Canadian industries and households are energy intensive. It has been estimated that Canada uses approximately 50 percent more energy per dollar of GDP than America (Djoudad *et al*., 2001). Consequently, the benefits of rising energy prices accruing to Canadian energy exports are outweighed by the costs to other industries, undermining Canada's competitiveness and causing a depreciation of the dollar.

For the period 1996-2005, which includes an oil price spike, however, the impact seems to have become positive. The intuitively appealing reason for this is that there has been a shift in the composition of Canadian external trade, such that its energy exports are increasing and so the direct effect of rising energy prices has begun to outweigh the indirect effect. Between 2000-04 Canadian energy exports grew from US$36 billion to US$53 billion, and exports of oil and related products grew from US$17 billion and US$27 billion.[15] The ratio of oil related exports to imports increased from 1.5 to approximately 1.8. These figures indicate a shift in the structure of Canada's energy trade; however this shift is not significant enough to explain the dramatic reversal in the coefficient exhibited in the error-correction model results; therefore the result should be viewed with caution nevertheless.

Table 5.2: Canada's error-correction model estimation results

Period	**Jan 1972 - Dec 2005**		**Jan 1972 – Dec 1991**		**Jan 1992 – Dec 2005**	
Variable	***Coefficient***	***p-value***	***Coefficient***	***p-value***	***Coefficient***	***p-value***
Adjustment parameter (α)	- 0.140	0.03	- 0.150	0.02	- 0.171	0.04
Constant (β_0)	- 0.010	0.00	- 0.020	0.00	- 0.020	0.00
Real Non-energy index (β_1)	0.792	0.00	0.600	0.00	0.718	0.00
Real Energy index (β_2)	- 0.029	0.35	- 0.395	0.00	0.359	0.00
Short term interest differential (φ_2)	0.130	0.00	0.158	0.01	0.162	0.07
Lagged change in Rfx (φ_1)	0.204	0.00	0.161	0.00	0.271	0.00
R-squared	0.236		0.236		0.298	

[15] Figures here are taken from UN COMTRADE statistical database. Energy products are taken to mean all of SITC 3, while oil and related products are SITC 333, 334 and 335.

Of all the countries studied, the results for New Zealand offer the best evidence that a country's real exchange rate converges to a long-run equilibrium, determined by the nation's commodity terms of trade (see *Table 5.3)*. All coefficients are significant and of expected sign, of a sensible scale, and reasonably stable over time. The explanatory power of the model is higher than those for the other countries. The R^2 indicates that this model can explain almost 30% of the month-to-month variation in the New Zealand dollar's real bilateral U.S. dollar exchange rate, an impressive result for a simple model containing only a few explanatory variables.

Table 5.3: New Zealand's error-correction model estimation results

Period	**Jan 1987 - Dec 2005**		**Jan 1987 – Dec 1995**		**Jan 1996 – Dec 2005**	
Variable	*Coefficient*	*p-value*	*Coefficient*	*p-value*	*Coefficient*	*p-value*
Adjustment parameter (α)	- 0.103	0.01	- 0.231	0.02	- 0.189	0.01
Constant (β_0)	- 0.030	0.00	- 0.010	0.00	- 0.010	0.00
Real Non-energy index (β_1)	0.675	0.00	0.600	0.00	0.815	0.00
Short term interest differential (φ_2)	0.136	0.04	0.232	0.00	0.261	0.01
Lagged change in Rfx (φ_1)	0.209	0.00	0.251	0.01	0.225	0.01
R-squared	0.298		0.367		0.368	

Over the full sample for Iceland, the error-correction model is a poor explanator of variation in the króna's real exchange rate, as shown by the number of insignificant coefficients (see *Table 5.4)*. Although the non-energy index in the cointegrating regression is significant, the adjustment parameter is not, indicating the króna is not adjusting towards an equilibrium predicted by Icelandic commodity export prices.

However, once the sample is reduced to include only data following the float of the króna in 2001, the model demonstrates an excellent fit, with all variables significant and of theoretically expected sign. In this period, the error-correction model for Iceland is apparently beginning to exhibit behaviour similar to the models for Australia, Canada, and New Zealand. Clearly, in Iceland it would seem that the missing ingredient in the equilibrium relationship between the real exchange rate and commodity prices before 2001 was a freely floating exchange rate regime. The managed float in existence prior to 2001 was apparently interfering with market forces and preventing adjustments to the króna's natural equilibrium. This is a theoretically appealing result, as it implies that when currencies are fixed, or even partially fixed, market forces are prevented from correcting disequilibrium and persistent misalignments of the value of the currency may occur. When the price of Iceland's exports rose under the previous exchange rate regime, the Central Bank of Iceland would soak up the resultant excess supply of foreign currency in order to maintain the predetermined exchange rate. Instead, the value of the free floating króna is determined by supply and demand in foreign currency markets and thus appreciates in the event of excess supply of foreign currency.

Table 5.4: Iceland's error-correction model estimation results

Period	**Jan 1991 - Dec 2005**		**Jan 2001 – Dec 2005**	
Variable	***Coefficient***	***p-value***	***Coefficient***	***p-value***
Adjustment parameter (α)	- 0.074	0.33	- 0.766	0.00
Constant (β_0)	0.010	0.98	0.077	0.00
Real Non-energy index (β_1)	0.467	0.00	0.416	0.00
Short term interest differential (φ_2)	- 0.016	0.85	- 0.610	0.00
Long term interest differential (φ_3)	- 0.073	0.37	- 0.449	0.00
Lagged change in Rfx (φ_1)	0.385	0.00	0.426	0.00
R-squared	0.154		0.295	

Although the results for Iceland support economic theory, they must also be viewed with caution, owing to the small sample size. Moreover, such a high adjustment parameter is suspicious, as it is well above those found for other countries; nevertheless this could be a result of a rapid adjustment in the currency toward equilibrium immediately following the float. Adjustments in response to disequilibrium may be more normal going forward, as the króna achieves a state of relative stability. Overall, the results for Iceland are most certainly intriguing and warrant further investigation in the future as more post-float data become available.

As with Iceland, the error-correction model for Norway does not fit well over the entire sample period (see *Table 5.5)*. This cannot be attributed to the monetary policy regime since the sample period only covers post-float observations. Since Norway is the only country for which the real effective exchange rate rather than the real US bilateral exchange rate was studied, I estimated an additional error-correction model for the latter. However, there was no improvement in the results. The Norwegian krone is often viewed as a pure petrocurrency; thus it is possible that the constructed commodity indices are underestimating the impact of oil. Various experimental changes to the indices, such as excluding the non-energy index and formulating the energy index as purely a function of the price of North Sea oil, were tested in the error-correction model.[16] Again, there was no impact on the results.

[16] The results of varying the indices are not presented in this paper, but can be obtained from the author upon request.

Table 5.5: Norway's error-correction model estimation results

Period	**Jan 1993 - Dec 2005**		**Jul 1999 – Dec 2005**		**Jan 1993 – Jun 1999**	
Exchange rate	***Real Effective***		***Real US$***		***Real effective***	
Variable	***Coefficient***	***p-value***	***Coefficient***	***p-value***	***Coefficient***	***p-value***
Adjustment parameter (α)	- 0.091	0.25	- 0.090	0.47	- 0.210	0.08
Constant (β_0)	0.010	0.13	0.010	0.98	0.010	0.65
Real Non-energy index (β_1)	- 0.367	0.00	- 0.101	0.65	- 0.122	0.00
Real Energy index (β_2)	0.878	0.00	0.621	0.00	0.465	0.03
Short term interest differential (φ_2)	0.023	0.87	- 0.128	0.47	0.433	0.09
Lagged change in Rfx (φ_1)	0.270	0.00	0.246	0.07	0.273	0.02
R-squared	0.07		0.08		0.17	

Testing a modified sample period for Norway, however, revealed an interesting result. The model appears to hold reasonably well for the period 1993-99. This is strange because as shown in *Figure 10* this is a period of relatively stable, though slightly declining energy prices. This runs counter to the theory that oil-exporting countries should have strong relationships with the price of oil, particularly during booms. In reality, however, the empirical evidence is weak for this theory (De Grauwe, 1996). Akram (2002) uses a different econometric framework to mine; yet he finds that the relationship between the krone and oil prices is non-linear in nature. He finds that although oil prices and the krone are positively related, the relationship is stronger when the price is either low or stable. So "both the level and trend-dependent effects seem to assign greater importance to particularly low oil prices in inducing exchange rate fluctuations than to particularly high oil prices," Akram (2002, p. 484). These features are supported by my error-correction model which exhibits a significant relationship for the 1993-1999 period of low and declining energy prices, but finds no significant relationship during the energy price boom post-1999.

The overall conclusion drawn from the error-correction models estimated in this paper is that the real exchange rate in each country exhibits a relationship with the real price of that country's commodity exports, though the strength and nature of the association varies between countries and across time periods. Although the R^2 values may appear low, it should be noted that the purpose of this framework it is not to create an exhaustive model for the month-on-month changes in the real exchange rate; rather, the objective is to assess whether or not the real exchange rates are adjusting towards their respective long-run equilibriums as determined by their country's commodity terms of trade. This phenomenon can be observed in the models for all countries studied, although at different times and in varying degrees. Moreover, Lafrance & van Norden (1995) note that error-correction models typically perform better over longer time horizons. On the whole, the models provide an endorsement of the branch of the *non-monetary approach* to exchange rate modelling which postulates that exogenous shocks to the commodity terms of trade are a fundamental determinant of real exchange rate fluctuations in the commodity currency economies.

5.2 A PRELIMINARY INVESTIGATION OF CURRENCY CONTAGION

A useful by-product of the error-correction models is that correlation in their residuals can be used as a preliminary indicator of currency contagion (Clinton, 2001). An accusation frequently made in the commodity currency economies is that the foreign exchange market does not adequately distinguish between their respective currencies. They are treated in a similar manner in response to news that does not affect the various economies equally. Moreover, proponents of the contagion theory claim that a currency may be impacted by news that is of no relevance, purely because such news affects another commodity currency. An example of this was the previously mentioned potential episode of contagion between Iceland and New Zealand in early 2006 (see Introduction).

A strong correlation between the components of exchange rates that are not explained by economic fundamentals (as measured residuals from the error-correction model) might be an indicator of such currency contagion. Since in this paper I have used a different measure of exchange rate value for Norway as compared to the other countries (the real effective rate, rather than the US bilateral rate) it must be excluded from analysis here. A positive correlation in the residuals for the other four nations is expected owing to the existence of factors, impacting the U.S., which are omitted from the error-correction models. The cross correlations are presented in *Table 5.6.*

Table 5.6: Cross correlation of U.S. real bilateral exchange rate residuals

	Australian $	Canadian $	New Zealand $	Icelandic kr
Australian $	1	0.311**	0.450**	-0.211*
Canadian $	0.311**	1	0.365**	0.225**
New Zealand $	0.450**	0.365**	1	0.369**
Icelandic kr	-0.211*	0.225**	0.369**	1

*** indicates signifance at the 5% level and * indicates significane at the 10% level.*

Correlations of close to zero provide reasonable evidence to refute the suggestion of contagion (Clinton, 2001). For the most part, the correlations are low enough. However, the correlations of the New Zealand dollar, particularly in relation to the Australian dollar, could perhaps lend some weight to the contagion hypothesis; whether this contagion is owing to commodity price dependency is an entirely different issue. It does not necessarily follow that it is a result of speculation and irrationality in foreign exchange rates either. The correlation could be because of other economic fundamental factors that are held in common but are not included in the error-correction models. For example, another plausible explanation for the sudden drop in the New Zealand dollar in February 2006, is that it was a negative reaction in currency markets to countries with excessive government debt levels, following the downgrade of Iceland's bond rating (The Economist, 2006). It should be noted that this analysis represents only a preliminary investigation. Much more extensive empirical work would be required to determine the true prevalence of currency contagion in these economies.

6. CONCLUSION

The main objective of this paper is to investigate the role of real commodity prices in determining the real exchange rate in the industrialised commodity currency economies of Australia, Canada, Iceland, New Zealand and Norway. In doing so, I analyse whether one particular branch of the *non-monetary approach* to explaining exchange rates – the branch focusing on exogenous shocks to a country's commodity terms of trade – can be used to model changes in the real exchange rate of these countries. My aim was not to create the most exhaustive and accurate model of these exchange rates, but rather to test whether a particular fundamental economic relationship espoused in various theories stands up to empirical testing, in the new commodity price environment and in relation to this unique sub-group of macroeconomies. That fundamental relationship is that a country's long-run equilibrium real exchange rate is determined by the world price of its commodity exports.

To this end, I use a simple error-correction framework, which contains interest rate differentials and commodity terms of trade indices as its independent variables. The results suggest that world commodity prices continue to exert a major influence on the exchange rate dynamics in developed, small open economies whose exports are concentrated in primary commodities.

The precise nature of the relationship differs from country to country. The results for New Zealand are most in line with the theory and expectations. Its commodity terms of trade variable has a strong, positive relationship with its real exchange rate, and changes in the real exchange rate seem to reflect an adjustment towards a long-run equilibrium. In the case of Australia, while there is a positive relationship between the real exchange rate and the non-energy commodity terms of trade, the energy terms of trade exhibits a negative relationship. Regardless of this, the model for Australia is consistently strong, and variables are significant, which confirms widely held beliefs regarding the Australian dollar's commodity dependence.

The results for Canada, Iceland and Norway are more curious. In the case of Canada I find the negative relationship between the real exchange rate and the energy terms of trade, which exists in my model for the 1970s, 1980s and first half of the 1990s, reverses sign during the period 1995-2005, and remains significant. This suggests a fundamental shift in the nature of the relationship between energy prices and the Canadian dollar. Although there are possible intuitive explanations for this, they do not seem to be sufficient to account for such a radical change. Accordingly, an avenue for future research is to undertake a more detailed empirical investigation of this result so as to be more certain of its accuracy. Should it stand up to further empirical testing, it would then be of interest to study the reasons behind this shift.

For Iceland I find that while the model exhibits little explanatory power when applied to data prior to the float of the króna, it performs significantly better post-float. A key prerequisite of the theory discussed in this paper is that, for the real exchange rate to reach its long-run equilibrium, free market forces must be allowed to operate without undue interference from governments or central banks. Hence, the float of the króna appears to have facilitated a rapid adjustment of its real exchange rate toward its long-run equilibrium, as determined by the commodity terms of trade. Another topic for future research would be to undertake a similar study once post-float data on the króna covers a long time period, as presently the sample size is too small for concrete and reliable conclusions to be drawn.

Finally, in the case of Norway I find further evidence of a non-linear relationship between the energy price index and the real krone exchange rate. The influence of oil prices on the real exchange rate tends to be stronger in periods of relatively low or declining oil prices, as compared to periods of high or escalating oil prices.

The findings of this paper are thus an endorsement of the *non-monetary approach* to modelling exchange rates, which would argue that currency fluctuations derive from necessary changes in currency market supply and demand, which are fundamentally determined by the real price of commodity exports. The other dominant approach that is applicable to this study is that of *exchange market psychology.* This approach would argue that foreign exchange markets pay less heed to fundamentals when it comes to commodity currencies, do not adequately differentiate between them, and engage in increased levels of speculation. The fact that my preliminary investigation into one feature of this approach – that of currency contagion – did not yield significant evidence cannot in itself be taken as a specific rebuke of any exchange market psychology-based model, and this approach remains an interesting area for further research.

The conflict between these two paradigms of the determinants of exchange rates mirrors the rising tide of debate in the economies studied, regarding the desirability of having a currency whose value is heavily tied to cycles and fluctuations in global commodity prices. This paper is set against this backdrop of increasing political and economic discourse. Overall, the message from the evidence presented here is clear: whether you are an economist, a politician, or simply an arm-chair critic, should you wish to explain movements in the real exchange rates of the industrialised commodity currencies, it would be wise to consider the price of fish.

APPENDIX

APPENDIX 1

Table A.1: Classification of SITC codes

Classification	SITC Code
Non-energy commodity exports	SITC 0 : Food and live animals
	SITC 1: Beverages and tobacco
	SITC 2: Crude materials, inedible, except fuels
	SITC 4: Animal and vegetable oils, fats and waxes
	SITC 6.7: Iron and steel
	SITC 6.8: Non-ferrous metals
	SITC 9.7: Gold, non-monetary (excluding gold ores and concentrates)
Energy commodity exports	SITC 3: Mineral fuels, lubricants and related materials
Non-commodity exports	SITC 5: Chemicals and related products
	SITC 6: Manufactured goods (excl. 6.7 and 6.8)
	SITC 7: Machinery and transport equipment
	SITC 8: Miscellaneous manufactured articles
	SITC 9: Commodities not elsewhere classified (excl 9.7)

APPENDIX 2

The country specific export price indices for Australia (non-energy and energy), Iceland (non-Energy) and Norway (non-Energy and energy) were calculated as follows:

Annual data on the total value of primary commodities for each country for period 2000-04 were obtained from the United Nations Commodity Trade Statistics Database (UN COMTRADE). I divide primary commodities between energy and non-energy categories on the basis of Standard International Trade Classifications. See Appendix 1 for the results of these classifications.

I calculate the preliminary individual energy commodity weights by taking the average value of each energy commodity export for 2000-04 and for each country, and dividing that result by the 2000-04 average of *total* energy exports for that country. The same method applies for calculating the individual non-energy commodity weights to use in the non-energy indices. In determining the final weightings, I exclude any commodity with an initial weighting of less than 0.5 percent to create a more manageable index. One would expect commodities with such low weightings to exert negligible influence on the index; therefore their exclusion should not bias results.

Data on commodity prices were primarily accessed from the IMF's IFS which produces U.S. dollar price indices for sixty-three energy and non-energy commodities. In instances when price statistics for a particular commodity were not available from the IFS, data were taken from the Thomson DataStream database. Unfortunately, some individual commodities had to be excluded from final weightings owing to the unavailability of data. Consequently, the relationship between the commodity indices and the real exchange rate will tend to be biased toward zero, even though the constructed commodity indices will be highly correlated with the 'true' indices.

Additionally, owing to classification differences between UNCOMTRADE and IMF/Thomson DataStream, it was necessary to make generalisations in the classification of commodities. For example, the IMF only produces one generic Fish index. Considering the high weighting of Fish in the Icelandic and Norwegian non-energy indices, perhaps it would be preferable to defragment these nations' fish exports into different breeds of fish which may exhibit different price behaviour. Nevertheless, the implicit assumption I make in constructing my indices is that commodities are homogenous. Fish is fish, wheat is wheat, uranium is uranium, and so on. While strictly speaking it may be preferable to divide each commodity down into additional sub-categories, it is not viable from a perspective of data availability. Moreover, none of the previous studies I encountered used more specialised commodity prices, so it should be acceptable to use of generic prices for the purpose of my paper.

After making all of the necessary exclusions, I determine the final weightings which are then held fixed over time. This Laspeyres fixed-weight commodity index is the geometrically-weighted index of the nominal prices of each countries significant commodity exports, where the nominal index is determined by:

$$NIndex = \exp\left\{\sum_{k=1}^{K}(W_k \cdot P_k)\right\} \quad where \quad W_k = \frac{(P_{jk}Q_{jk})}{(\sum_k P_{jk}Q_{jk})}$$

P_k is the index of the U.S. dollar world price of commodity *k*; W_k is the individual commodity weight, calculated as the value of exports of commodity *k* divided by the total value of all *K* commodities, for the constant base period *j* (2000-2004); and *Q* is the quantity of exports of commodity *k*.

I deflate the nominal indices by the U.S. CPI to attain real indices. Previous studies have found that results are not particularly sensitive to the selection of deflator; therefore the general and broadly applicable U.S. CPI is a reasonable choice.

I perform robustness checks of the commodity price indices by comparing the Canadian and New Zealand indices (acquired from the Bank of Canada and Australia and New Zealand Banking Group respectively) with indices I constructed using the methodology described above. The constructed and already provided indices exhibit a high degree of correlation, which is an indicator of the accuracy of the constructed commodity price indices for Australia, Iceland and Norway.

APPENDIX 3

Table A3.1: Non-energy commodity price index composition

Australia	%	*Canada*	%	*Iceland*	%	*New Zealand*	%	*Norway*	%
Barley	2.2	Barley	1.8	Fish	58.1	Kiwi Fruit	3.7	Fish	38.9
Beef	10.6	Canola	2.0	Fish meal	8.2	Wholemeal	10.6	Fish meal	1.7
Cotton	3.4	Corn	1.2	Fish oil	2.0	Skim MP	3.7	Shrimp	2.6
Wheat	9.7	Wheat	8.5	Shrimp	6.2	Apples	3.1	Iron	5.1
Hides	1.8	Beef	9.4	Aluminium	22.2	Fish	6.7	Silver	1.5
Wool	8.0	Swine	4.9	Ferro-Silicon	3.3	Casein	6.7	Copper	1.4
Iron ore	14.3	Cod	0.1			Butter	6.5	Nickel	7.3
Lead	1.0	Lobster	0.5			Cheese	8.3	Aluminium	31.7
Nickel	4.3	Salmon	0.6			Beef	9.4	Zinc	1.5
Aluminium	21.2	Gold	4.3			Lamb	12.5	Ferro-Alloy	4.7
Copper	6.7	Silver	0.9			Wool	7.7	Softwood	1.5
Gold	14.1	Aluminium	4.6			Skins	1.6	Pulp	2.2
Zinc	1.8	Copper	4.5			Aluminium	8.3		
Uranium	1.1	Nickel	3.7			Sawn timber	4.6		
		Zinc	4.2			Logs	3.5		
		Potash	2.0			Pulp	3.1		
		Sulphur	1.4						
		Lumber	13.8						
		Newsprint	12.8						
		Pulp	18.9						
TOTAL	100		100		100		100		100

Table A3.2: Energy commodity price index composition

Australia	%	*Canada*	%	*Norway*	%
Crude Petroleum	35.7	Crude Petroleum	62.3	Crude Petroleum	78.4
Natural Gas	14.0	Natural Gas	29.9	Natural Gas	21.6
Coal	50.3	Coal	7.8		
TOTAL	100		100		100

APPENDIX 4

The Augmented Dicker Fuller (ADF) test for stationarity test the null hypothesis of non-stationarity against the alternate hypothesis of stationarity. The lag length for each test is determined according to the procedure recommended by Campbell and Perron (1991). In the tables below *** denotes the null is rejected at the 1% level, ** denotes rejection at the 5% level, and * denotes rejection at the 10% level.

Table A.4.1: Unit root tests, Real exchange rates

Country	ADF lag length	ADF statistic
Australia	16	- 2.411
Canada	17	- 2.055
Iceland	12	- 2.568
New Zealand	11	- 2.285
Norway	12	- 1.594

Table A4.2: Unit root tests, Commodity price indices

Variable	ADF lag length	ADF statistic
Australia Non-energy	10	- 1.822
Australia Energy	11	- 1.880
Canada Non-energy	19	- 2.096
Canada Energy	23	- 1.403
Iceland Non-energy	15	- 1.764
New Zealand Non-energy	12	- 2.068
Nor Non-Energy	15	- 2.230
Nor Energy	21	- 0.160

Table A4.3: Unit root tests, interest rate differentials

Country	ADF lag length	ADF statistic
Australia	18	- 2.847**
Canada	14	- 2.887**
Iceland	19	- 3.201**
New Zealand	16	- 3.845***
Norway	23	- 3.809***

The Engle-Granger Augmented Dickey-Fuller (EG-ADF) test for cointegration tests the null hypothesis of no cointegration against the alternate of cointegration. The lag length for each test is determined according to the procedure recommended by Campbell and Perron (1991). In the tables below *** denotes the null is rejected at the 1% level, ** denotes rejection at the 5% level, and * denotes rejection at the 10% level.

Table A4.4: Cointegration tests

Country	EG-ADF lag length	EG-AGF test statistic
Australia	16	- 4.856***
Canada	18	- 3.734**
Iceland	12	- 3.120*
New Zealand	10	- 3.735**
Norway	11	- 3.522*

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