What Determines Real Exchange Rates?

The Nordic Countries*

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Abstract

This paper presents a model yielding testable implications concerning the long-run co-movements of real exchange rates, relative productivity, the trade balance and terms of trade. Countries with higher productivity, trade deficits or improved terms of trade are found to have more appreciated real exchange rates, with the main channel of transmission working through the relative price of nontraded goods. Exogenous terms of trade shocks are found to be the most important determinant of long run movements in the real exchange rate for Denmark and Norway, while demand shocks account for most of the long run variance in the real exchange rate for Finland and Sweden.

Keywords: Real exchange rates; cointegration; variance decomposition.

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1. Introduction

According to the purchasing power parity (PPP) hypothesis, all movements in the real exchange rates are transitory. There are, however, both theoretical reasons why PPP may not hold and empirical evidence of large deviations from PPP.[1] The most popular model of why the real exchange rate would vary over time is due to Balassa (1964) and Samuelson (1964). According to their model, real exchange rates of countries with high productivity growth in the tradable sectors appreciate. A rise in productivity in the traded good sector will raise wages in the entire economy, and producers of nontraded goods will only be able to meet the higher wages if there is a rise in the relative price of nontradable goods. De Gregorio and Wolf (1994) extended this model to allow for changes in terms of trade, where improved terms of trade induce an appreciation in the equilibrium real exchange rate. In recent years, there has been a renewed interest in the relationship between international payments and the real exchange rate ("the transfer problem"); the question whether debtor (creditor) countries tend to have more depreciated (appreciated) real exchange rates. For example, Lane and Milesi-Ferretti (2000) developed an intertemporal model of the transfer effect that yields testable implications on the long-run co-movements of the real exchange rate, external positions, relative GDP and terms of trade.[2]

Recently, there has been a revived interest in international macroeconomics in a research strategy aimed at bridging the gap between ad hoc monetary models and modern intertemporal models.[3] These micro-founded models of imperfect competition have an intertemporal dimension, emphasizing the budget constraint as a key element in the analysis. In this paper, I use the same framework as this "new open economy macroeconomics" to derive a simple model of the equilibrium real exchange rate, where countries with a trade deficit, higher productivity, or improved terms of trade are found

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[1] For surveys of this literature, see e.g. Rogoff (1996) and Froot and Rogoff (1995).

[2] A large number of empirical papers try to estimate the equilibrium real exchange rates using some or all of the variables: relative productivity, terms of trade and/or net foreign asset (see e.g. Alberola, E, Cervero, S, Lopez, H, and Ubide, A, (1999), Canzoneri, M, Cumby, R and Diba, B. (1999), MacDonald, R. (2000) and Clark, P and Macdonald, R. (1998)).

[3] The redux model by Obstfeld and Rogoff (1995) is generally considered as the starting point for this literature. Lane (2001) surveys the new open economy literature.

to have a more appreciated real exchange rate, with the main channel of transmission working through the relative price of nontraded goods.

This paper differs from previous theoretical studies in that I consider the long-run relationship between the trade balance and the real exchange rate, and not the long-run relationship between net foreign assets and the real exchange rate. I show that the approach of using net foreign assets instead of the trade balance is potentially restrictive for several reasons. For example, rates of return vary across countries, over time and between different categories of assets and liabilities. Moreover, the current account varies over time, and it is completely consistent with economic theory to have a current account deficit or surplus in the long run and also that the economy is a net foreign claimant or debtor in the long run. The same type of mechanisms between the real exchange rate and the trade balance has been emphasized in a few empirical studies. For example, Lane and Milesi-Ferretti (2002) examine the link between the net foreign asset position, the trade balance and the real exchange rate. Among other things, they show that the relationship between the net foreign asset and the trade balance within and across countries is related to the rates of return on external assets and liabilities and the rate of output growth.

In the next section, I develop an intertemporal optimizing model yielding testable implications on the long-run co-movements of real exchange rates, relative productivity, the trade balance and terms of trade. An endogenous price of nontradables is the main mechanism linking the real exchange rate with these variables. The intuition is straightforward; a rise in the productivity in the traded good sector or improvements in the terms of trade will increase wages in the entire economy. Producers of nontraded goods will only be able to meet the higher wages if there is a rise in the relative price of nontraded goods, i.e. in the supply side of the economy. A trade deficit raises the consumer's disposable income and hence the demand for nontradable goods, requiring an increase in the relative price of nontradables and hence, a real appreciation. Thus, in this model, both supply and demand factors determine the relative price of nontradables and hence, the real exchange rate.

Based on the theoretical work, I use the Johansen maximum likelihood approach to investigate how real exchange rates are related to relative productivity, exogenous terms of trade shocks and the trade balance, using data on the four Nordic countries in the period 1975 to 2001. The empirical results indicate a statistically significant and economically meaningful relationship between the real exchange rate and the other three variables, i.e. countries with higher productivity, trade deficits or improved terms of trade are found to have more appreciated real exchange rates.

A growing empirical literature uses variance decomposition to investigate whether demand or supply shocks account for most of the long-run variance in the real exchange rate. For example, Clarida and Gali (1994), Lastrapes (1992) and Roger (1999) found that demand shocks account for most of the changes in the real exchange rate, while Alexius (2001) found that supply shocks dominate the long-run variance in the real exchange rate for each of the four Nordic countries. In this paper, I find both demand and terms of trade shocks to be important. Demand shocks account for most of the long-run variance in the real exchange rate for Finland and Sweden, but for Norway and Denmark, exogenous terms of trade shocks (the real price of oil) are found to be the most important determinant of long run movements in the real exchange rate.

The paper proceeds as follows: Section 2 presents the model. In section 3, I describe the data and briefly discuss the empirical model. The main results are reported and discussed in section 4. Finally, section 5 summarizes and provides the conclusions.

2. Theory

The world consists of two countries, the home and the foreign country, where the home country is small relative to the rest of the world.[4] I consider a three-good economy with two tradable and one nontradable type of goods. Tradable goods consist of imports, entirely produced abroad and consumed domestically, and domestically produced tradable goods. Thus, private agents derive utility from the consumption of nontradable, imported and domestically produced tradable goods, while the economy produces the nontradable and one tradable type of good.

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[4]The framework builds on models by Lane and Milesi-Ferretti (2000), Tille (2000) and Obstfeld and Rogoff (1995).

2.1 Households

The objective of the representative household in the home country is to choose a path of consumption and saving that maximizes the discounted lifetime utility

$$U_t = \sum_{s=0}^{\infty} b^s \left[\ln(C_{t+s})\right], \qquad (1)$$

where $b \in (0,1)$ is the consumer's discount factor. C is defined as a consumption basket with a constant elasticity of substitution between nontradable and tradable goods equal to unity, where tradable goods consist of domestically and foreign produced goods. Hence, the overall consumption basket, C, is a Cobb-Douglas aggregate of nontradable, imported and domestically produced tradable goods

$$C_t = \left(C_t^N\right)^{1-n}\left(\left(C_t^{IM}\right)^{v}\left(C_t^T\right)^{1-v}\right)^{n}, \qquad (2)$$

where C^N, C^T and C^{IM} represent the consumption of nontradable, domestically produced tradable and imported goods, respectively.[5] Households can invest in an international real bond, denominated in units of imported goods. The budget constraint (the current account equation) is given by

$$B_{t+1} - (1+r_t)B_t = P_t^N Y_t^N + P_t^T Y_t^T - P_t^N C_t^N - P_t^T C_t^T - C_t^{IM}, \qquad (3)$$

where B denotes real bonds that pay a real interest rate r, which may vary exogenously over time. P_t^N is the price of the nontradable good, and P_t^T is the export price. The imported good is the numeraire. By this definition, P_t^T is the terms of trade (the ratio of

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[5]It is straightforward and consistent with the model to consider C^N, C^{IM} and C^T as types of goods, and that for each type of good, there exists a continuum of brands. Hence, C^N, C^{IM} and C^T can, in turn, be seen as CES aggregates across brands index by x.

$$C_t^N = \left[\int_0^1 (C^N(x))^{\frac{q-1}{q}} dx\right]^{\frac{q}{q-1}}, \quad C_t^T = \left[\int_0^1 (C^T(x))^{\frac{q-1}{q}} dx\right]^{\frac{q}{q-1}}, \quad C_t^{IM} = \left[\int_0^1 (C^{IM}(x))^{\frac{q-1}{q}} dx\right]^{\frac{q}{q-1}},$$

where $q > 1$ is the elasticity of substitution between two brands produced in the same sector. $C^N(x), C^{IM}(x)$ and $C^T(x)$ denote the consumption of a particular brand x in the nontradable, imported and domestic tradable goods sector, respectively.

export prices to import prices). Y_t^N is the production of nontradable goods and Y_t^T is the production of tradable goods. The optimal consumption decisions are given by

$$\frac{C_t^N}{C_t^{IM}} = \frac{1-n}{nv}\left(P_t^N\right)^{-1} \tag{4}$$

$$\frac{C_t^T}{C_t^{IM}} = \frac{1-v}{v}\left(P_t^T\right)^{-1} \tag{5}$$

$$\frac{C_{t+1}}{C_t} = \left(\frac{P_t^c}{P_{t+1}^c}\right)(1+r_t\ )b\ . \tag{6}$$

Equation (6) is the Euler condition reflecting the optimal intertemporal allocation of consumption, equation (4) links the consumption of nontraded and traded goods and equation (5) links the consumption of domestic and foreign produced goods. P^c is the consumer price index in the home country

$$P_t^c = \frac{\left(P_t^N\right)^{1-n}(1)^{nv}\left(P_t^T\right)^{n(1-v\ )}}{(1-n)^{(1-n)}\left(nv\ \right)^{nv}\ n(1-v\ )^{n(1-v\ )}}\ . \tag{7}$$

As shown in appendix A, the household saving rate and hence, the current account, can be written as follows

$$B_{t+1} - B_t = CA_t = \left(P_t^T Y_t^T - \overline{P}_t^T \overline{Y}_t^T\right) + (r_t - \overline{r}_t)B_t + (1 - \frac{1-b}{b}\sum_{s=t}^{\infty} R_{t,s})(\overline{r}_t B_t + \overline{P}_t^T \overline{Y}_t^T)\ , \tag{8}$$

where $\overline{P}^T\overline{Y}^T$ and $\overline{r}$ are the permanent levels of $P^T Y^T$ and r, respectively.[6,7] According to equation (8), there are three separate reasons why the home country has a current account deficit or surplus. First, an increase in output or terms of trade above its permanent level contributes to a current account surplus because of consumption

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[6] See Obstfeld and Rogoff (1996) for a similar derivation of the current account.
[7]For empirical support that the current account can be explained with a present value model incorporating terms of trade and variable interest rates, see e.g. Bergin and Sheffrin (2000) and Adedeji (2001).

smoothing. Second, if the economy is a net foreign claimant and the world interest rate currently exceeds its permanent level, the current account is unusually high as people save to smooth their unusually high asset income into the future. The situation is reversed if the economy is a net foreign debtor. Third, $1-\frac{1-b}{b}\sum_{s=t}^{\infty}R_{t,s}$ captures the effect of differences between the market discount factor, $R_{r,s}$, and the consumer's discount factor, b. If the market discount factor exceeds (is below) the consumer's discount factor, consumption will, on average, be shrinking (increasing) over time, hence the country runs a current account deficit (surplus) even if output, terms of trade and the real interest rate are equal to their steady state values. Thus, in this model, it is completely consistent to have a current account deficit or surplus in the long run, and also that the economy is a net foreign claimant or debtor in the long run.

2.2 Production

The production of tradable and nontradable goods is given by

$$Y_t^T = A^T (L_t^T)^g (Z^T)^{1-g} \tag{9}$$

$$Y_t^N = A^N (L_t^N)^g (Z^N)^{1-g}, \tag{10}$$

where $0 \le g \le 1$. L^x is the labor input in sector x and A^x the productivity in sector x (x = N, T). We assume labor to be inelastically supplied at L, so in equilibrium $L = L^N + L^T$. Z^T and Z^N are specific inputs in the tradable and nontradable sector, respectively. Throughout, we will assume perfectly flexible prices and wages, an assumption that makes this analysis most applicable over a medium/long-term horizon of perhaps two to four years. Hence, solving the firm's problem, we get that the competitive price is equal to the marginal cost, given by

$$P_t^N = \frac{W_t}{g}\left(\frac{\left(Y_t^N\right)^{1-g}}{A^N (Z^N)^{1-g}}\right)^{\frac{1}{g}}, P_t^T = \frac{W_t}{g}\left(\frac{\left(Y_t^T\right)^{1-g}}{A^T (Z^T)^{1-g}}\right)^{\frac{1}{g}}, \tag{11}$$

where w denotes wages. The law of one price is assumed to hold for tradable goods, so that P^T is given in the world market. Combining the price equations, we obtain the following expression for the relative production of tradable and nontradable goods

$$\frac{Y_t^T}{Y_t^N} = \left(\frac{P_t^T}{P_t^N}\right)^{\frac{g}{1-g}} \left(\frac{A^T}{A^N}\right)^{\frac{1}{1-g}} \left(\frac{Z^T}{Z^N}\right). \tag{12}$$

The relative production of tradable and nontradable goods depends on relative productivity, the specific input Z and the relative price of nontradable goods. For example, the production of tradable goods will increase if the relative productivity in the tradable sector increases and/or if the relative price of nontradable goods decreases.

2.3 Equilibrium

Combining equation (4) that links the consumption of nontraded and imported goods, equation (5) that links the consumption of imported and domestically produced traded goods, the budget constraint, the market clearing condition $Y_t^N = C_t^N$ and the supply side of the economy (equation (12)), we can solve for the equilibrium price level, obtaining

$$P_t^N = k_1 \left(\left(P_t^T\right)^g \frac{A^T}{A^N} \right) \left(\frac{P_t^T Y_t^T + r_t B_t - CA_t}{Y_t^T} \right)^{1-g}, \tag{13}$$

where $k_1 > 0$.[8] According to this expression, the relative price of nontradables increases if the relative productivity in the tradable sector increases, the terms of trade improve, the investment income on the net foreign asset position increases, or the surplus of the current account decreases. The intuition is straightforward. A rise in the productivity in the traded good sector or improvements in the terms of trade, will increase wages in the entire economy. Producers of nontraded goods will only be able to meet the higher wages if there is a rise in the relative price of nontraded goods, i.e. the supply side of the

[8] $k_1 = \left(\frac{1-n}{n}\right)^{1-g} \left(\frac{Z^T}{Z^N}\right)^{1-g}$

economy. Improved terms of trade also raise the consumer's disposable income and hence, the demand for nontradable goods, requiring an increase in the relative price of nontradables. In the same way, an increase in the level of net foreign assets or higher rates of return (if the economy is a net foreign claimant) raise the consumer's disposable income and hence, the demand for nontradable goods. Finally, a current account deficit (a reduction in savings) increases consumption and hence, the demand for nontradable goods, requiring an increase in the relative price of nontradables and hence a real appreciation. Thus, both supply and demand factors determine the relative price of nontradables.

Using the definition of the budget constraint (equation (3)), we can also express the price of nontradable goods in terms of the relative productivity in the tradable and nontradable sector, terms of trade and the ratio of imports (IM) to exports (EX),

$$P_t^N = k_1 \left(\left(P_t^T\right)^g \frac{A^T}{A^N} \right) \left(\frac{\left(\frac{IM_t}{EX_t}\right)}{v + \left(\frac{1-v}{P_t^T}\right)\left(\frac{IM_t}{EX_t}\right)} \right)^{1-g} \tag{14}$$

where the ratio of imports to exports (the trade balance) depends on the terms of trade, the net foreign asset position, the rate of return and the current account. Hence, improved productivity in the tradable sector, improved terms of trade or a trade deficit will imply an increase in the relative price of nontraded goods. According to equation (14), the size of an increase (decrease) in the relative price of nontradable goods of a trade deficit (surplus) depends on parameter v. For example, in the extreme case of a closed economy (i.e. $v = 0$), the trade balance will have no effect on the relative price of nontradable goods, because there is always an external balance in a closed economy.

There are two interesting cases when g is equal to one and zero, respectively. In the first case, when the marginal productivity of labor is constant between the two sectors, thus when g is equal to one, we can, according to equation (14), see that the relative price of non-tradable goods is entirely determined by relative productivity and the terms of trade, and independent of the demand conditions. Thus, in the special case when g is equal to one, equation (14) replicates the De Gregorio and Wolf (1994) results that the relative price of non-tradable goods is entirely determined by relative productivity and terms of trade. In the other extreme case when g is equal to zero, the supply side of the economy no longer exists, because in this case, the production of tradable and nontradable goods will be endowments only depending on the productivity in each sector. Thus, when g is equal to zero, only the demand side of the economy will affect the relative price of nontradables and hence, the real exchange rate.

The rest of the world can be treated as a closed economy consuming and producing tradable and nontradable goods (i.e. $v = 0$). Households in the rest of the world have the same type of maximizing problem as the home country, i.e. they choose a path of consumption and saving maximizing their discounted lifetime utility, and the overall consumption basket is a Cobb-Douglas aggregate of nontradable and traded goods. As in the home country, the production of tradable and nontradable goods depends on relative productivity, sector-specific input Z, and labor input. Solving the model in the case of a closed economy, we get that the equilibrium foreign price of nontradable goods is given by

$$P_t^{N*} = k^* \left(\frac{A^{T*}}{A^{N*}} \right), \tag{15}$$

where $k^* > 0$.[9] The foreign price of nontradable goods is entirely determined by relative productivity and independent of the demand conditions, for in a closed economy, there is always an external balance (no exports or imports). The foreign consumer price index is given by

$$P_t^{c*} = \frac{(P_t^{N*})^{1-n}(1)^n}{(1-n)^{1-n} n^n}, \tag{16}$$

where the consumer price index and the price of nontradable goods are denominated in units of traded goods.

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[9] $k^* = \left(\frac{1-n}{n} \right)^{1-g} \left(\frac{Z^{T*}}{Z^{N*}} \right)^{1-g}$

The real exchange rate is defined as the ratio of the foreign consumer price index measured in domestic currency, to the domestic consumer price index

$$Q_t = \frac{P_t^{c*}}{P_t^c} \tag{17}$$

$$= k_2 \frac{(P_t^{N*})^{1-n}(1)^n}{(P_t^N)^{1-n}(1)^{nv}(P_t^T)^{n(1-v)}}.$$

Combining equations (14)-(17), the real exchange rate is given by

$$Q = k_2 \left(\left((P_t^T)^g \frac{A^T A^{N*}}{A^N A^{T*}} \right) \left(\frac{\left(\frac{IM_t}{EX_t}\right)}{v + \frac{(1-v)}{P_t^T}\left(\frac{IM_t}{EX_t}\right)} \right)^{1-g} \right)^{n-1} \left(P_t^T\right)^{-n(1-v)}, \tag{18}$$

where $k_2 > 0$.[10] According to equation (18), countries with a faster relative productivity growth, increased imports relative to exports or improved terms of trade, will have more appreciated real exchange rates, with the main channel of transmission working through the relative price of nontraded goods. The terms of trade may influence the CPI-based real exchange rate in two different ways: Indirectly through a wealth effect on the relative price of nontradables and directly through the relative price of domestically produced tradable goods. In the extreme case when domestic consumers only consume nontradable and imported goods (i.e. $v = 1$), the terms of trade may only indirectly influence the real exchange rate through a wealth effect on the relative price of nontradables. In the other extreme case when only tradable goods exist (i.e. $n = 0$), the terms of trade and the real exchange rate coincide.

A log-linear approximation of equation (18) forms the basis for the empirical work in subsequent sections. The theoretical expression for the real exchange rate (equation (18)) is derived under the assumption of completely flexible prices and wages, which makes the analysis most applicable over a long-term horizon. In the short run,

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[10] $k_2 = ((nv^{nv}(1-v)^{n(1-v)})/n^n)(k^*/k_1)^{1-n}$

when wages and nominal prices are predetermined, monetary policy and other financial factors can have an effect on the real exchange rate through changes in the nominal exchange rate. In the long run, these transitory effects on the real exchange rate will vanish, however.

3. Data and Econometric Methodology

3.1 Data description

The data set covers four Nordic countries (Denmark, Finland, Norway and Sweden) between 1975 Q1- 2001 Q1. Data on the real effective exchange rate (*q*), the ratio of imports to exports (*im-ex*), relative productivity ($y - y^*$), terms of trade (*tot*) and the real price of oil (*oil*) are collected from the OECD database Main Economic Indicators. The data are seasonally adjusted and all variables are expressed in logs. 1985 Q1 is the base year for all indices. Figures C.1-C.4 show the evolution of the real exchange rate, relative productivity, the ratio of imports to exports, terms of trade and the real price of oil. Appendix B provides more details on data sources and definitions for all variables.

For each country, the real exchange rate index (q) is a CPI-based effective real exchange rate constructed as a competition weighted sum of exchange rate series for ten OECD countries.[11] The model predicts a unique relationship between the real exchange rate and the relative productivity in tradable and non-tradable sectors. Given the problem involved in obtaining data on total factor productivity in the tradable and non-tradable sectors, I follow Alexius and Nilsson (2000) and use relative real GDP ($y - y^*$) as a proxy for this variable. Moreover, if relative GDP growth is primarily driven by productivity, and productivity growth is concentrated to the tradable sector, a unique relationship between relative GDP and relative productivity in tradable and non-tradable sectors rate emerges. For each country, the foreign GDP series is constructed using the same methodology and trade weights as in the real exchange rate index.

To capture the effect of changes in terms of trade, I will use two alternative measures: the real price of oil and the terms of trade. The model presented in section 2

[11]The weights can be found in Table C.1, Appendix C.

suggests a unique relationship between the terms of trade and the real exchange rate. This will be a causal relationship if the terms of trade are set independently of domestic conditions by world markets, i.e. the terms of trade are exogenous to an individual country if it exerts no market power in its import/export markets. The latter is unlikely to be the case for industrial countries like the Nordic countries, except possibly in the very long run. To capture the effect of exogenous changes in the terms of trade, I follow Amano and Van Norden (1995) and use the domestic price of oil (*oil*). I do not claim oil price to be the only exogenous factor causing changes in the terms of trade, but I consider them to be a good proxy for exogenous terms of trade shocks. For example, Backus and Crucini (2000) find that oil accounts for a considerable part of the variations in the terms of trade over the last twenty-five years. Furthermore, comparing the oil price to the terms of trade series in Figure C.1-C.4 shows that the real oil price indeed appears to account for most of the major movements in the terms of trade. However, for those skeptical of the use of oil as a proxy for exogenous changes in the terms of trade, I will also present additional results using terms of trade rather than the real price of oil.

The effects of all of these variables on the equilibrium exchange rate are summarized below, where the expected sign is given in brackets

$$q_t = f(\overset{(-)}{y - y^*}, \overset{(+/-)}{oil}, \overset{(-)}{im - ex},) \,. \tag{19}$$

An important issue in time series regression is the degree of integration of the variables, since integrated variables require a different empirical treatment from stationary variables, due to the well-know problem of spurious regression. The augmented Dicky-Fuller (ADF) tests reported in Table C.2 suggest that all these variables are nonstationary in levels and stationary in first differences. Consequently, the fundamental variables and the real exchange rate are assumed to be I(1).

3.2 Johansen procedure

Owing to the non-stationarity of the time series, the real effective exchange rate is estimated in a vector error correction model (VECM), based on the procedure developed by Johansen (1988, 1991).[12] The Johansen maximum likelihood procedure consists of estimating an error correction representation of a vector autoregressive (VAR) model of the order k. The empirical analysis starts with an unrestricted VECM taking the following form

$$\Delta x_t = \Pi x_{t-1} + \sum_{j=1}^{k-1} \Gamma_j \Delta x_{t-j} + m + bz_t + e_t, \qquad (20)$$

where x_t is an n-dimensional column vector, m a vector of constants, z_t a vector of deterministic (exogenous) variables, such as seasonal dummies and intervention dummies, and e_t denotes the vector of white noise disturbances. In this setting, the variable vector consists of four variables, $x = [q, im - ex, y - y^*, oil]$. Γ_j represents the short-run dynamics and the lagged level term, and Πx_{t-1} is the error correction term of stationary linear combinations of the x variables. The number of cointegration relationships corresponds to the rank of the matrix, Π. If Π is of either full rank, n, or zero rank, there will be no cointegration amongst the elements in the long-run relationship. If however, Π is of reduced rank, r where r < n, then there will exist matrices a and b, such that $\Pi = ab'$. a is an adjustment matrix, indicating the speed at which the system responds to deviations from the equilibrium level of the exchange rate in the last period, and is b a matrix of cointegration vectors, implying that the long-run relationship $b' x_t$ is stationary, even if x_t is non-stationary. Hence, the existence of the VECM model, relative to say a VAR in first differences, depends upon the existence of cointegration.

4. Empirical Analysis

4.1 Model specification

Prior to estimating the lag length parameter in equation (20), and the cointegration rank, it is useful to consider the possibility that some of the nonstationary features in our system are due to deterministic breaks and regime shifts. If this is the case, a valid

[12]For a detailed discussion of the Johansen procedure see Johansen (1995).

cointegration analysis requires conditioning on the nonstationary influence of such deterministic breaks.

Non-normality of the residuals might be a problem why a set of deterministic variables is included to overcome the most severe problems in the exchange rate equation. To account for devaluations and shifts to a floating exchange rate regime, the following dummies are included in the regression

$$D_{i,t} = \begin{cases} 1 & if \quad t \in I_i, \quad i = 1,2,3,4 \\ 0 & otherwise \end{cases},$$

where $I_1^F = \{1991:4\}$ and $I_2^F = \{1992:4\}$ for Finland, $I_1^N = \{1977:3\}$ and $I_2^N = \{1986:2\}$ for Norway and $I_1^S = \{1977:3\}$, $I_2^S = \{1981:3\}$, $I_3^S = \{1982:4\}$ and $I_4^S = \{1992:4\}$ for Sweden. The seasonal pattern in the data has already been taken care of by seasonally adjusting the data prior to estimating the VAR-model.

In a second step, the lag order (k) of the system is determined by estimating an unrestricted VAR model in levels, and using the information criteria proposed by Akaike and Schwarz to determine the lag length. In addition, residual tests may indicate misspecifications. In particular, a VAR model produces a biased estimate in the presence of autocorrelation. Hence, the number of lags is determined using information criteria, but chosen sufficiently high to remove residual autocorrelation. This procedure results in three lags for Finland and Sweden, four for Denmark and two for Norway (see Table C.3 for details).

4.2 Cointegration tests

The number of cointegration vectors (r) is verified by determining the cointegration rank, using the trace test and the max-eigenvalue test statistic. According to Table 1, both the trace test and the max-eigenvalue test suggest one cointegrated relationship for Finland, Norway and Sweden, i.e. one equilibrium relationship between the non-stationary variables (q, $y - y^*$, *im-ex* and *oil*). The trace test indicates two cointegration vectors in the case of Denmark, while the max-eigenvalue test only indicates one. Since there has been a growing consensus that both these statistics suffer from a small-sample bias, too often tending to reject the null hypothesis of no cointegration, it seems preferable to use one vector. These results, which confirm the theory laid out in section 2, have led us to base the remaining analysis on the cointegration rank of $r = 1$ for all countries.

Table 1: Cointegration rank

	Trace test				$l-\max$ test			
H_0:	$r = 0$	$r \leq 1$	$r \leq 2$	$r \leq 3$	$r = 0$	$r \leq 1$	$r \leq 2$	$r \leq 3$
Denmark	87.22	40.82	18.68	8.05	46.40	21.14	11.63	8.05
Finland	57.62	25.08	12.95	3.66	32.53	12.13	9.24	3.66
Norway	62.94	32.50	12.73	4.88	28.44	21.77	7.85	4.88
Sweden	58.89	30.56	11.76	2.44	28.34	18.76	9.32	2.44
Critical values:	53.12	34.91	19.24	9.24	28.14	22.00	15.67	9.24

Note: Critical values at the 5% level.

4.3 Cointegration relations

Table 2 shows the unrestricted estimates of the cointegration vector. Most of the coefficients have the correct sign, and are statistically significant at standard levels. High relative productivity appreciates the real exchange rate in the long run for Denmark, Norway and Sweden, but depreciates the real exchange rate for Finland. A decrease in the real oil price appreciates the real exchange rate for Denmark, Finland and Sweden, but depreciates the real exchange rate for Norway, as expected from theory, because a sustained rise in oil prices would result in more favorable terms of trade for an oil exporting country like Norway. A deteriorated trade balance results in a real appreciation for Finland, Norway and Sweden, but results in a real depreciation in the case of Denmark. Thus, all variables except relative productivity for Finland and the trade balance for Denmark have the expected signs.

More information about the long-run relationship between the real exchange rate and the fundamental variables can be extracted from the data by investigating various linear restrictions on the cointegration vector. For example, it may be the case that only some of the variables, relative productivity, the real price of oil and imports relative to exports, significantly enter into the cointegration vector. Table 3 reports the results from these tests, which are likelihood ratio tests of linear restrictions on the cointegration

Table 2: Unrestricted estimates of the cointegrating vector (t-values in parentheses)

Country	q	$y-y^*$	*oil*	*im-ex*
Denmark	1.00	0.19 (3.97)	-0.06 (4.71)	-0.15 (2.17)
Finland	1.00	-0.05 (0.97)	-0.05 (3.22)	0.62 (6.87)
Norway	1.00	0.12 (2.85)	0.08 (4.24)	0.14 (4.91)
Sweden	1.00	0.52 (2.69)	-0.03 (2.45)	0.60 (4.22)

Table 3: Likelihood ratio tests of excluding economic fundamentals

H_0	Denmark	Finland	Norway	Sweden
$b^{y-y^*}=0$	7.51 (0.00)	0.26 (0.61)	12.11 (0.00)	11.93 (0.00)
$b^{oil}=0$	21.48 (0.00)	6.84 (0.00)	28.18 (0.00)	9.95 (0.00)
$b^{im-ex}=0$	2.32 (0.14)	17.88 (0.00)	13.96 (0.00)	18.34 (0.00)

Note: p-values in parentheses. The likelihood ratio test is $c^2(rp)$ distributed, where r is the number of cointegrated vectors and p the number of restrictions.

Table 4: Estimates of restricted cointegration vectors and the speed of the adjustment parameter a (t-values in parentheses)

Country	q	$y-y^*$	*oil*	*im-ex*	a
Denmark	1.00	0.12 (4.57)	-0.07 (5.86)		0.19 (3.81)
Finland	1.00		-0.06 (3.71)	0.59 (6.94)	0.12 (3.49)
Norway	1.00	0.12 (2.85)	0.08 (4.24)	0.14 (4.91)	0.22 (2.91)
Sweden	1.00	0.52 (2.69)	-0.03 (2.45)	0.60 (4.22)	0.11 (2.66)

Note: a is the speed of the adjustment parameter vector.[13] According to Table 3, all variables enter significantly (at standard levels) into the cointegration vector, except relative productivity in the case of Finland and trade balance in the case of Denmark.

Owing to the insignificance of relative productivity and the trade balance in the case of Finland and Denmark, respectively, the cointegration vector may be more efficiently estimated if zero restrictions are imposed for Denmark and Finland. Table 4 shows the resulting restricted estimates of the cointegration vectors. After imposing these restrictions, all variables have the correct sign and are statistically significant at standard levels.

According to Table 4, an increase in relative productivity or a deteriorated trade balance results in a real appreciation in the exchange rate of all countries. A permanent rise in oil prices results in a weakening of the real exchange rate for Denmark, Finland and Sweden. Conversely, a permanent rise in oil prices results in an appreciation in the real exchange rate for Norway, because a sustained rise in oil prices will result in more favorable terms of trade for an oil exporting country like Norway. All variables are expressed in logs, which means, for example, the coefficient of 0.08 in the case of Norway indicates that a permanent rise in real oil prices of, say 10 percent, will result in a long lasting real appreciation in the real exchange rate of 0.8 percent.

Most of the coefficients seem to be of plausible magnitude. The coefficients for imports relative to exports are of the same magnitude for Sweden and Finland, but somewhat lower for Norway. The low coefficient on all variables except the real price of oil for Norway is probably due to its high degree of dependence on the petroleum sector. The point estimate of the coefficients on relative productivity is the same for Denmark and Norway, but seems to be somewhat larger for Sweden. In previous studies, the effect of relative productivity on the equilibrium real exchange rate has been found to be in the range of 0.1-1.0 (see e.g. Alexius and Nilsson (2000) and De Gregorio and Wolf (1994)).[14]

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[13]I have also performed likelihood ratio tests of a joint exclusion of variables, but these tests are rejected for all countries.

[14]In Alexius (2001), the point estimates of the coefficient on relative GDP is somewhat larger, they vary between 0.4 –4.4 for the Nordic countries.

The coefficients of the error correction terms, i.e. the speed of the adjustment parameter a, are negative for all four Nordic countries and highly significant. Thus, the condition for a long-term stable equilibrium is satisfied. The parameter values of 0.19, 0.12, 0.22 and 0.11 for Denmark, Finland, Norway and Sweden, respectively, suggest a half-life period of shocks of about 3.3, 5.4, 2.8 and 5.9 quarters for Denmark, Finland, Norway and Sweden, respectively.[15] In other words, the differential between the actual real exchange rate and the equilibrium real exchange rate is reduced by half, three to six quarters after an exogenous shock.

Figures 1 – 4 show actual real exchange rates and the long-term equilibrium real exchange rates for the four Nordic countries. The long-term equilibrium real exchange rate is calculated from the cointegration vector reported in Table 4. I call it the long-term equilibrium real exchange rate, because the theoretical expression for the real exchange rate (equation (18)) and hence, also the cointegration vector, is derived under the assumption of completely flexible prices and wages, which makes the analysis most applicable over a long-term horizon. In the short run, when wages and nominal prices are predetermined, monetary policy and other financial factors can have an effect on the real exchange rate through changes in the nominal exchange rate. But these transitory effects on the real exchange rate will vanish in the long run. Thus, the unexplained movements in the real exchange rate can be seen as a long-term exchange rate misalignment, because they reflect an exchange rate behavior that cannot be accounted for by fundamentals, but rather by transitory and random factors.

For all countries the equilibrium real exchange rate and the actual real exchange rate have the same trend path, but for all countries there are also periods with substantial deviations from the equilibrium level. Starting with the Danish real exchange rate, deviations from the equilibrium level have been moderate, apart from the period 1979-1981 which coincided with the second oil price shock in 1979-1980. Perhaps the most striking feature of both the actual and the equilibrium real exchange rate for Denmark is how closely these are related to the real price of oil, i.e. exogenous terms of trade shocks seem to be the most important determinant of the real exchange rate in the long run. According to the theoretical expression for the real exchange rate (equation (18)), terms

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[15] The half-life period is calculated as: $\log(0.5)/\log(1-a)$.

Figure 1: Denmark

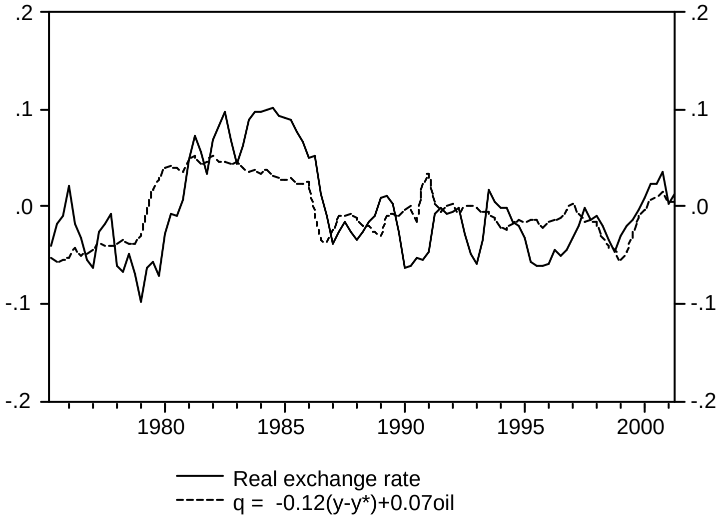


Figure 2: Finland

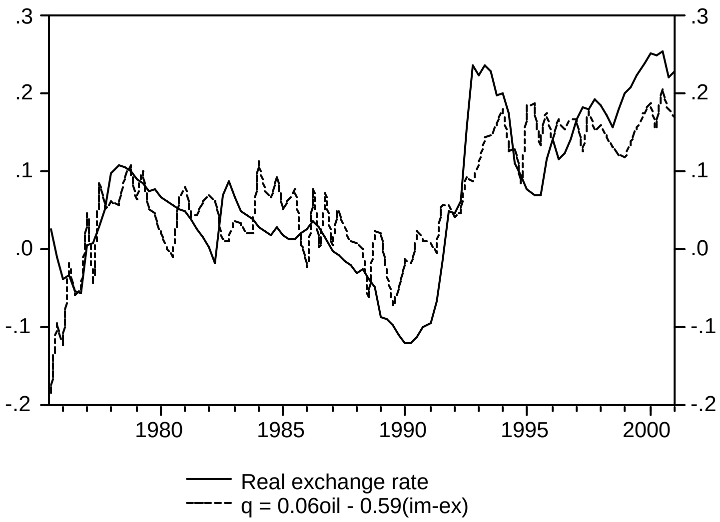


Figure 3: Norway

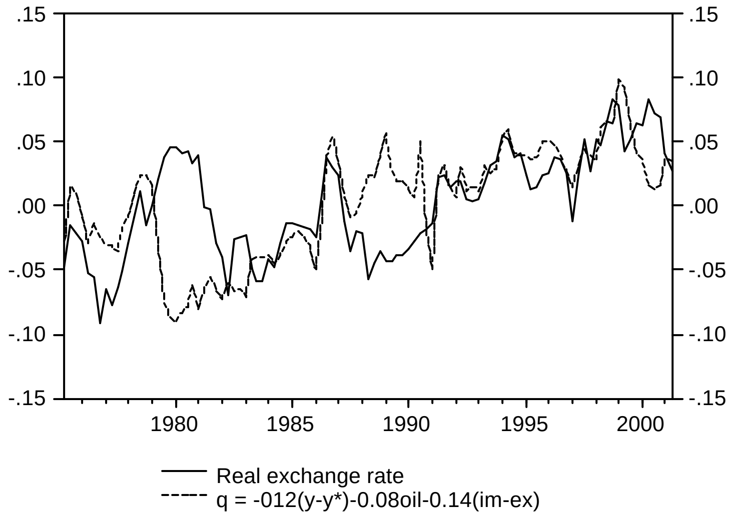
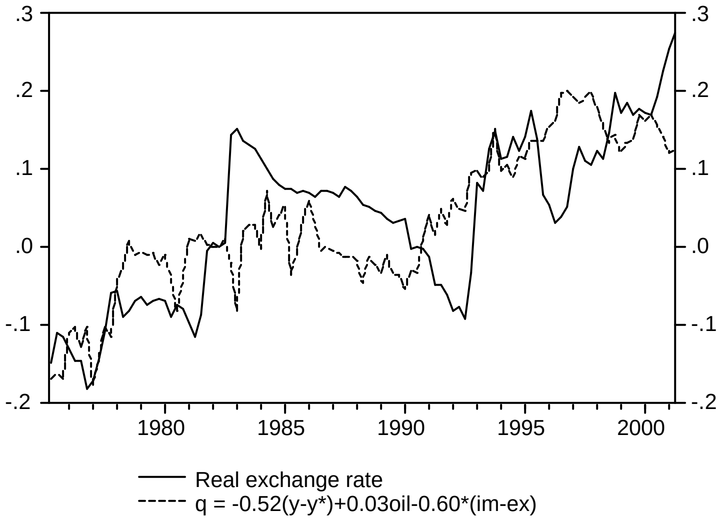


Figure 4: Sweden



of trade shocks are the most important determinants of the real exchange rate if the Danish people mostly consume tradable goods (i.e. n almost equal to one) and a considerable amount of domestically produced tradable goods. A number of factors seem to support these two conditions for Denmark. First, Denmark exports a great deal of livestock, amounting to around ten percent of total exports, and Danes will thus consume a considerable amount of domestically produced tradable goods (livestock). Second, Denmark is a smaller than the other Nordic countries, so its goods might be more tradable because of lower transport costs etc.

The Finnish real exchange rate displays a strong depreciation trend for both the actual and the equilibrium exchange rate. In the period 1975-1989, there were only small deviations from the equilibrium level. When there was a depreciation in the equilibrium rate at the end of 1980, the actual exchange rate remained overvalued for about two years before the markka was floated, and the actual rate surpassed the equilibrium rate. Subsequently, the actual real exchange rate remained undervalued until around 1994, when the actual exchange rate seems to have converged back to a level broadly in line with the fundamentals.

For Norway, the most striking feature is how closely the equilibrium and the actual real exchange rate are related. For example, during 1982-1987 and 1991-2000, they almost coincide. The close relation in these periods is due to the strong connection between the real price of oil and both the actual and the equilibrium real exchange rate.

But there are also periods of substantial deviations from the equilibrium level. For example, around 1979-1980, the oil price shock caused an appreciation in the equilibrium real exchange rate, but the actual real exchange rate remained undervalued for two years before it also appreciated.

Finally, the Swedish real exchange rate displays a strong depreciation trend for both the actual and the equilibrium exchange rate, but deviations from the equilibrium level have tended to be large. Before abandoning the fixed exchange rate regime in November 1992, most of the deviations can be related to the Swedish devaluation policy. For example, the real exchange rate was overvalued before the devaluations in 1977, 1981 and 1992. The expectation is the devaluation in October 1982, which can be described as an offensive devaluation with the aim of dampening the recession at the beginning of the 1980's. After abandoning the fixed exchange rate in 1992, the actual exchange rate is broadly in line with fundamentals until 1996, when the actual exchange rate underwent a short period of appreciation and subsequently, a strong depreciation trend until 1999 that is not captured by fundamentals. Around 2000, the actual real exchange rate converged back to a level in line with the fundamentals, but the strong depreciation in the real exchange rate since 2000 is not captured by the equilibrium real exchange rate.

4.4 Estimates with terms of trade as the explanatory variable

Estimates of the cointegration vector when we use terms of trade instead of oil are reported in Table 5. According to Table 5, all variables except the relative productivity for Finland and Norway show the expected sign. The likelihood ratio test of linear restrictions on the cointegration vector, reported in Table 6, indicates that all variables enter significantly into the cointegration vector except relative productivity and the trade balance for Denmark, and relative productivity for Norway. Table 7 shows the resulting restricted estimates of the cointegration vectors. After imposing these restrictions, all the coefficients have the correct sign, except relative productivity in the case of Finland. Accordingly, these results are broadly similar to the results I presented earlier using oil price. The only major difference is that relative productivity is found to be less important when using terms of trade instead of oil prices.

Table 5: Unrestricted estimates of the cointegrating vector (t-values in parentheses)

Country	q	$y-y^*$	*tot*	*im-ex*
Denmark	1.00	0.05 (1.87)	0.99 (8.99)	0.06 (0.78)
Finland	1.00	−0.12 (2.56)	0.40 (4.43)	0.64 (5.76)
Norway	1.00	−0.06 (1.96)	0.14 (4.32)	0.15 (5.19)
Sweden	1.00	0.43 (2.30)	0.61 (4.99)	0.63 (4.19)

Table 6: Likelihood ratio tests of excluding economic fundamentals

H_0	Denmark	Finland	Norway	Sweden
$b^{y-y^*} = 0$	2.21 (0.14)	6.83 (0.00)	2.43 (0.13)	7.55 (0.00)
$b^{tot} = 0$	29.43 (0.00)	15.21 (0.00)	19.18 (0.00)	13.78 (0.00)
$b^{im-ex} = 0$	0.28 (0.60)	17.88 (0.00)	28.66 (0.00)	17.84 (0.00)

Note: p-values in parentheses. The likelihood ratio test is $c^2(rp)$ distributed, where r is the number of cointegrated vectors and p the number of restrictions.

Table 7: Estimates of restricted cointegration vectors (t-values in parentheses)

Country	q	$y-y^*$	*tot*	*im-ex*
Denmark	1.00		0.76 (9.39)	
Finland	1.00	−0.12 (2.56)	0.40 (4.43)	0.64 (5.76)
Norway	1.00		0.09 (4.10)	0.10 (6.17)
Sweden	1.00	0.43 (2.30)	0.61 (4.99)	0.63 (4.19)

4.5 Variance decomposition

To investigate the relative importance of the three different shocks ((*y-y*), oil* and *im-ex*), I use variance decomposition. The variance decomposition method is attractive since it tells us how important a particular shock is relative to the other shocks for explaining fluctuations in the real exchange rate.

In the above section, we found the existence of one cointegration relationship for the variable vector $x = \lfloor q, im-ex, y-y^*, oil \rfloor$ for all countries. Hence, as we have four variables and one cointegration vector, the system is driven by three common trends, including three permanent and one temporary shock. Following Warne (1993), the cointegrated VAR model (equation (20)) can be rewritten as a common trend model

$$x_t = x_0 + \Psi t_t + \Phi(L) n_t , \tag{21}$$

where Ψt_t constitutes the permanent component of x_t and $\Phi(L) n_t$ constitutes the transitory component of x_t. The loading matrix Ψ determines how the variables in x_t are affected by stochastic trends. As we have four variables and one cointegrating vector, there are three common trends

$$t_t = m + t_{t-1} + j_t , \tag{22}$$

where j_t is a 3×1 vector of structural shocks with a permanent effect on the variables in the model. I label these shocks as oil price shock, supply (productivity) shock and demand shock. In terms of the theoretical model, these can be considered as permanent shocks to P^T, A^T and rB. The three permanent shocks in j_t are allowed to enter into the transitory shocks u_t, whereby shocks to the stochastic trends also affect the short-run dynamics of x_t.

In order to identify the structural shocks, we need to identify the parameters in the Ψ matrix that, in turn, determine the long-run effect of the permanent shocks. According to Warne (1993), ((n-r)(n-r-1))/2 = 3, and further restrictions are needed to identify the permanent shocks, when we have four variables and one cointegrating vector.[16] I use the following identifying assumptions: (i) only oil shocks have permanent effects on the real price of oil and (ii) demand shocks do not affect relative productivity in the long run.

Given the cointegration vector and the identifying restrictions, the common trends model can be estimated. The common trends model produces variance decompositions of the real exchange rate at different horizons. The relative importance of different shocks for different horizon is presented in Table 8. For Denmark and Finland, there are

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[16] See Warne (1993) for a detailed discussion of the number of restrictions needed for exact identification.

Table 8: Variance decompositions in the real exchange rate k years ahead

Country:	Denmark			Finland		
Horizon		k			k	
	1	5	∞	1	5	∞
oil	0.26	0.65	0.61	0.02	0.10	0.14
supply	0.10	0.24	0.39			
demand				0.22	0.72	0.86
transitory	0.64	0.11	0.00	0.76	0.18	0.00
Sum	1.00	1.00	1.00	1.00	1.00	1.00

Country:	Norway			Sweden		
Horizon		k			k	
	1	5	∞	1	5	∞
oil	0.21	0.79	0.84	0.00	0.09	0.12
supply	0.05	0.10	0.14	0.02	0.17	0.34
demand	0.17	0.09	0.02	0.16	0.51	0.54
transitory	0.57	0.02	0.00	0.82	0.23	0.00
Sum	1.00	1.00	1.00	1.00	1.00	1.00

Note: the transitory shock is the part of the shocks not explained by other variables in the model.

only two permanent shocks, because for these countries, the cointegration vector only contains three variables.[17]

The short-run impact of different shocks is found for k equal to 1, the medium-run (business cycle) impact is found for k equal to 5 and the long-run effect for k equal to ∞. In Table 8, transitory shocks mean changes in the real exchange rate not caused by any of the permanent shocks: oil, supply or demand. In the short run, transitory shocks account for most of the forecast error variance in the real exchange rate for all countries. In the medium run, the model captures most of the movements in the real exchange rate for Denmark, Finland and Sweden and almost all of the movements in the real exchange rate for Norway. For example, on a business cycle frequency in the case of Sweden, 17 percent of the variance in the real exchange rate are due to supply shocks, 9 percent to oil price shocks, 51 percent to demand shocks and 23 percent are due to shocks not captured in the model.

Finally, the long-run forecast error variance decompositions reveal what structural shocks have caused the long-run movements in the real exchange rate. As expected for Norway, almost the entire long-run variance in the real exchange rate is due to oil price

[17] $x = [q, y - y^*, oil]$ for Denmark and $x = [q, im - ex, oil]$ for Finland.

shocks (84 percent). For Denmark, most of the long-run variance is also due to oil shocks, but supply shocks also have a substantial influence on the long-run variance in the real exchange rate. For Finland, most of the long-run variance in the real exchange is due to demand shocks. In the case of Sweden, most of the long run variance is also due to demand shocks, but also supply and oil shocks have a substantial influence on the long-run variance in the real exchange rate. Hence, exogenous terms of trade shocks account for most of the long-run variance in the real exchange rate for Denmark and Norway, while demand shocks account for most of the long-run variance in the real exchange rate for Finland and Sweden.

According to Table 8, there is some support for the approach pointed out by Amano and Van Norden (1995) that the real price of oil should explain most of the long-run variance in the real exchange rate, particularly for Norway and Denmark. The Balassa-Samuelson approach that relative productivity should explain most of the long-run variance in the real exchange rate also receives some support for all four Nordic countries. However, particularly for Finland and Sweden, demand shocks also seem to be important determinants of the real exchange rate.

As mentioned above, Clarida and Gali (1994), Lastrapes (1992) and Roger (1999) found that demand shocks account for most of the changes in the real exchange rate, Alexius (2001), on the other hand, found that supply shocks dominate the long-run variance in the real exchange rate for each of the four Nordic countries. It is difficult to compare the results in this paper with those previous studies, because I have another definition of supply and demand shocks and it is unclear if oil price shocks should be interpreted as a supply and/or a demand shock.

5. Conclusions

This paper examines the long-term forces driving the real exchange rate. According to the PPP hypothesis, all movements in the real exchange rates are transitory. There are, however, both theoretical reasons why PPP may not hold and empirical evidence against PPP. The most common explanation is differentials in productivity between countries (i.e. the supply side of the economy), but also other factors such as consumer preferences and the transfer effect (i.e. the demand side of the economy) have been emphasized in the literature. While a substantial body of empirical literature exists on how both supply and demand factors affect real exchange rate determination, the literature tends to focus on one of the two effects, suggesting the possibility of an excluded variable bias.

In this paper, I instead develop an intertemporal optimizing model where both supply and demand factors should be important determinants of the real exchange rate. In short, a country with higher productivity, trade deficits or improved terms of trade should experience a real appreciation. The empirical results indicate that most of these variables are important determinates of long-run movements in the real exchange rate. Exogenous terms of trade shocks are found to be the most important determinants of long-run movements in the real exchange rate for Denmark and Norway. For Finland, most of the long-run variance in the real exchange rate is due to demand shocks. Finally, for Sweden, most of the long-run variance is due to demand shocks, but supply and exogenous terms of trade shocks also have a substantial influence on the long-run variance in the real exchange rate.

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Appendix A: The Current Account[18]

Using the market clearing condition $Y_t^N = C_t^N$ and equation (5) that links the consumption of imported and domestically produced traded goods; the budget constraint (equation (3)) can be rewritten as

$$B_{t+1} - (1+r_t)B_t = P_t^N Y_t^N + P_t^T Y_t^T - P_t^N C_t^N - P_t^T C_t^T - C_t^{IM}$$

$$= P_t^T Y_t^T - \frac{C_t^{IM}}{v}. \qquad \text{(A.1)}$$

Solving the budget constraint (equation (A.1)) forward, we get that

$$\sum_{s=t}^{\infty} R_{t,s} \frac{C_s^{IM}}{v} = (1+r_t)B_t + \sum_{s=t}^{\infty} R_{t,s} P_s^T Y_s^T\,, \qquad \text{(A.2)}$$

[18]See Obstfeld and Rogoff (1996) for a similar derivation of the current account.

where $R_{t,s}$ is the market discount factor for date s consumption on date $t \le s$, i.e. the relative price of date s consumption in terms of date t consumption.[19,20] Substituting the Euler equation into equation (A.2) and solving for C_t^{IM}, we obtain

$$C_t^{IM} = \frac{(1-b)v}{b}\left((1+r_t)B_t + \sum_{t=s}^{\infty} R_{t,s} P_s^T Y_s^T\right). \tag{A.3}$$

The accumulation of net foreign assets claims (the current account) between period t and t+1 is given by

$$CA_t = B_{t+1} - B_t = P_t^T Y_t^T + r_t B_t - \frac{C_t^{IM}}{v}, \tag{A.4}$$

substituting equation (A.3) into equation (A.4), we get that

$$\begin{aligned} CA_t &= P_t^T Y_t^T + r_t B_t - \frac{1-b}{b}\left((1+r_t)B_t + \sum_{t=s}^{\infty} R_{t,s} P_s^T Y_s^T\right) \\ &= \left(P_t^T Y_t^T - \overline{P}_t^T \overline{Y}_t^T\right) + (r_t - \overline{r}_t)B_t + (1 - \frac{1-b}{b}\sum_{s=t}^{\infty} R_{t,s})(\overline{r}_t B_t + \overline{P}_t^T \overline{Y}_t^T), \end{aligned} \tag{A.5}$$

where $\overline{P}_t^T \overline{Y}_t^T = \dfrac{\sum_{s=t}^{\infty} R_{t,s} P_s^T Y_s^T}{\sum_{s=t}^{\infty} R_{t,s}}$ and $\overline{r}_t = \dfrac{\sum_{s=t}^{\infty} R_{t,s} r_s}{\sum_{s=t}^{\infty} R_{t,s}}$ is the permanent level of $P^T Y^T$ and r.

$1 - \dfrac{1-b}{b}\sum_{s=t}^{\infty} R_{t,s}$ captures the effect of differences between the market discount factor $R_{r,s}$ and the consumer's discount factor, b.

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[19] The derivation of this constraint assumes that the transversality condition (*no-Ponzi-game* condition) $\lim_{t \to \infty} R_{t,t+T} B_{t+1+t|t} = 0$ always holds.

[20] $R_{r,s} = \dfrac{1}{\prod_{t=t+1}^{s}(1+r_t)}$

Appendix B: Data Sources and Definitions

The data set covers four Nordic countries (Denmark, Finland, Norway and Sweden) between 1975 Q1- 2001 Q1. The data are seasonally adjusted and all variables are expressed in logs.

Real exchange rate (q): For each country, the real exchange rate index (q) is a CPI-based effective real exchange rate constructed as a competition weighted sum of exchange rate series for ten OECD countries (The weights can be found in Table C.1, Appendix C). Source: OECD database Main Economic Indicators.

Relative productivity ($y - y^*$): Real GDP in the home country relative to a weighted average of real GDP in trading partners (i.e., the foreign GDP series is constructed using the same methodology and trade weights as in the real exchange rate index). Source: OECD database Main Economic Indicators.

The trade balance (*im-ex*): the ratio of total imports to total exports. Source: OECD database Main Economic Indicators.

Terms of trade (*tot*): are calculated as the ratio between the unit value of exports and the unit value of imports. Source: OECD database Main Economic Indicators.

The real price of oil (*oil*): The spot price index of oil is converted to real terms using the foreign CPI-price level (the foreign CPI-price index is constructed using the same methodology and trade weights as in the real exchange rate index). Source: OECD database Main Economic Indicators.

Appendix C

Table C.1: Weights to different countries in the real exchange rate index

Country	Denmark	Finland	Norway	Sweden
Denmark		5.19	10.29	6.85
Finland	3.70		4.90	8.18
France	9.71	8.89	5.88	8.75
Germany	33.97	24.74	19.52	27.26
Italy	6.51	7.26	5.86	7.40
Japan	9.58	9.18	6.62	6.36
Norway	5.24	3.56		6.83
Sweden	8.56	14.22	22.81	
United Kingdom	10.60	12.89	14.14	14.14
United States	12.13	14.07	9.98	14.23
Sum	100.00	100.00	100.00	100.00

Table C.2: Unit root tests

	Denmark		Finland		Norway		Sweden	
	L	D	L	D	L	D	L	D
q	-2.16	-5.19**	-2.27	-3.83**	-2.30	-5.19**	-1.33	-5.09**
*y-y**	-1.43	-3.68**	-2.76	-5.65**	-1.86	-3.04*	-1.65	-3.68**
oil	-2.13	-5.81**	-1.98	-5.82**	-1.99	-5.70**	-2.13	-5.81**
tot	-2.35	-3.79**	-1.60	-4.36**	-2.54	-4.83**	-1.73	-3.96**
im-ex	-0.76	-5.91**	-2.44	-5.27**	-1.51	-4.87**	-1.55	-5.89**

Note: **/* = error probability 1%, 5%. Critical values: 1% -3.50 and 5% -2.89. L=Levels, D = Differences.

Table C.3: Model specification tests

Country	AIC	SC	NM p-value	LM(1) p-value	LM(4) p-value	Preferred lags
Denmark	6	1	0.13	0.62	0.23	4
Finland	6	2	0.09	0.21	0.29	3
Norway	6	2	0.43	0.14	0.13	2
Sweden	1	1	0.02	0.12	0.42	3

Note: LM(p) is a Lagrange Multiplier test for autocorrelation of the order p and NM is a multivariate non-normality test. AIC = Akaike information criteria and SC = Schwarz information criteria. The Lagrange Multiplier test and the normality test are only reported for the preferred lag length.

Figure C.1: Denmark

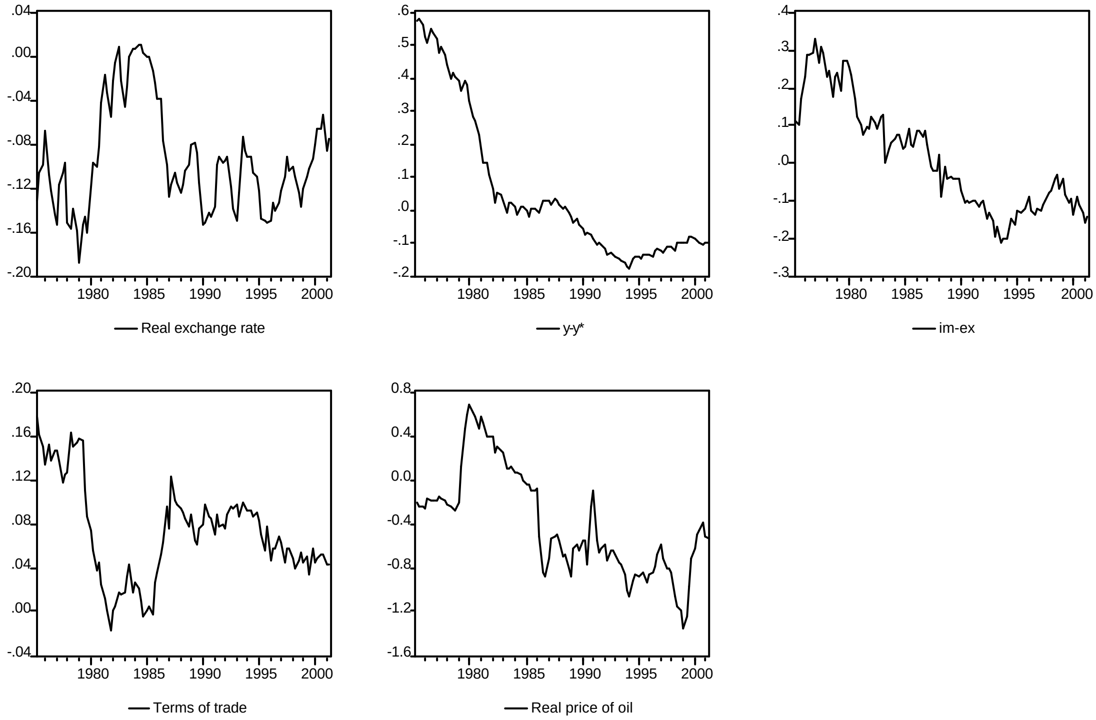

Figure C.2: Finland

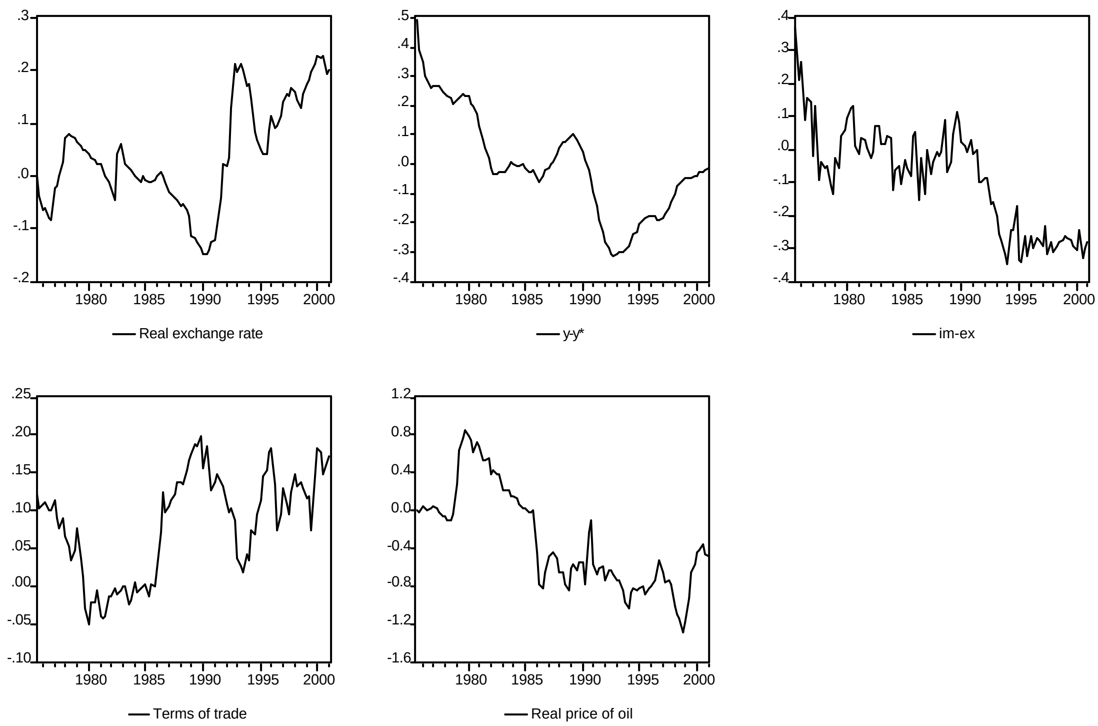

Figure C.3: Norway

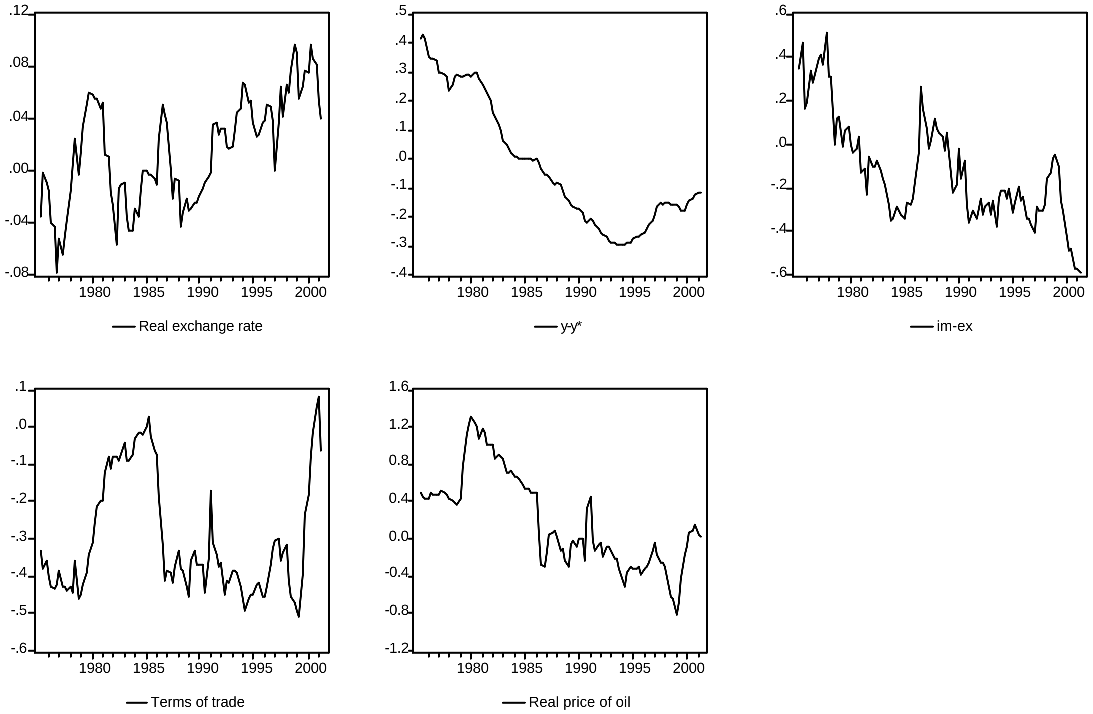

Figure C.4: Sweden