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# Cointegration and the stabilizing role of exchange rates

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## COINTEGRATION AND THE STABILIZING ROLE OF EXCHANGE RATES

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# Cointegration and the stabilizing role of exchange rates

Annika Alexius\* and Erik Post†

February 2006

## Abstract

We show that empirical results concerning the behavior of floating exchange rates differ between otherwise identical cointegrated and non-cointegrated VAR models. In particular, virtually all ten-year movements in nominal exchange rates are due to fundamental supply and demand shocks when long run equilibrium relationships between the levels of the variables are included in the empirical specification. Another major difference between the models with the opposite implication for the shock creation versus shock absorption debate is that non-fundamental exchange rate shocks have much larger effects on output and inflation in the cointegrated models. Finally, impulse response functions in the first difference specification die out within a year whereas adjustment to long run equilibrium continues for up to ten years in the cointegrated models. Hence a correct specification of the long-run equilibrium dynamics of exchange rates is essential for capturing also short-run behavior of exchange rates.

**Key words:** Exchange rates, asymmetric shocks, structural VAR, cointegration

**JEL classifications:** F31, C32.

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# 1 Introduction

Freely floating nominal exchange rates are extremely variable relative to other macroeconomic variables. The variance of changes in floating exchange rates is ten to 20 times as large as the variances of inflation or output growth. Only changes in stock prices and oil prices have variances of comparable magnitudes. Are these movements stabilizing responses to fundamental shocks or do they emanate from the foreign exchange market itself, hence adding additional, destabilizing variability to the economy? What role does a floating exchange rate play in the economic system?

Exchange rates can be characterized as destabilizing to the extent that their movements emanate from the exchange rate itself and actually affect the real economy. On the other hand, to the extent that the exchange rate moves to counteract the effects of shocks to the economy, it fulfills a stabilizing function. Studies evaluating the relative merits of fixed and floating exchange rates frequently assume that a floating exchange rate stabilize shocks (Friedman (1953), Mundell (1961)). A recent example can be found in Pilbeam (2004).<sup>1</sup> For instance, the exchange rate appreciates in response to an unanticipated increase in domestic demand relative to foreign demand, thus pushing domestic output down towards long-run equilibrium and reducing inflation towards its equilibrium. It is however far from clear that such stabilizing behavior can be observed in the data.

Previous empirical studies of the stabilizing role of floating exchange rates have reached different conclusions, although with a clear predominance of the view that it is difficult to document clear evidence of stabilizing properties. It can be argued that whether exchange rates are found to be stabilizing or

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<sup>1</sup>The stabilizing behaviour of exchange rates with respect to asymmetric demand shocks follow from the way assuming that uncovered interest parity holds.

destabilizing is partly a function the empirical specification. In particular, the documented relationship between fundamental variables and exchange rates is considerably stronger in studies using cointegration techniques than in studies where long run equilibrium relationships between exchange rates and e.g. relative price levels or relative real output are not taken into account. Alexius (2005) argues that her result that the effect of productivity shocks on real exchange rates is much larger than what is found in previous studies is due to the inclusion of long run equilibrium relationships in the statical model. Artis and Ehrmann (2000) use a model without cointegration and concludes that most movements in exchange rates are due to exchange rate shocks in four of the five countries studied and that the relationship between exchange rates and fundamental supply and demand shocks is weak. Similarly, Bjorneland (2004) use a model without cointegration and conclude that exchange rates are destabilizing, as do Borghijs and Kuijs (2004).

In this paper we estimate otherwise identical structural VAR models with and without cointegration. Thereby we are able to isolate the effects of the assumptions concerning long-run equilibrium relationships between nominal exchange rates and the fundamental variables on the relevant results. Bilateral exchange rates of five small open economies (Australia, Canada, New Zealand, Sweden, Switzerland) versus the United States in order to investigate the effects of cointegration or the presence of long-run equilibrium relationships between the variables on the results. It turns out that allowing cointegration increases the share of fundamental shocks in the variance decompositions, correspondingly decreasing the influence of exchange rate noise. It also affects the impulse responses in the sense that a shock has much more prolonged effects on the exchange rate as the variables adjust to a new long-run equilibrium. The directions of the impulse responses are

however not more stabilizing in the cointegrated models.

The question whether exchange rates are stabilizing or destabilizing has straight forward interpretations in terms of output from a structural VAR. Variance decompositions answer questions about the sources of movements in a variable. Hence they can be used to discriminate between movements in the nominal exchange rate that are stabilizing responses to e.g. asymmetric demand shocks and movements that originate from the exchange rate itself e.g. are potentially destabilizing. To investigate whether the shocks created by the exchange rate actually do destabilize the economy, we study the variance decompositions of output in the first place and inflation in the second. Hence we may conclude that exchange rates are destabilizing to the extent that (i) movements stem from the exchange rate itself and (ii) these non-fundamental exchange rate shocks cause movements in output and inflation. Exchange rates are stabilizing to the extent that (i) their movements are responses to fundamental shocks and (ii) they move in the direction required to stabilize the economy. For instance, if demand increases in Sweden but not in the foreign country, the exchange rate should appreciate to counteract the effects of this asymmetric shock. A large fraction of movements that are due to fundamental structural shocks does not necessarily imply that the exchange rate actually stabilizes shocks because variance decompositions do not contain information about the direction of the movements. Impulse response functions however supply information about the direction of the movement in a variable in response to a shock in another variable. Comparing the results with and without cointegration hence amounts to comparing variance decompositions and impulse response functions with and without cointegration.

## 2 Data

The data used in this paper are collected from the OECDs data base Main Economic Indicators. We use three time series for each country: Real expenditure approach seasonally adjusted GDP ( $y$ ) data, total consumer price indices ( $p$ ) and nominal exchange rates ( $e$ , defined as domestic currency per US dollar. Thus an increase in  $e$  is a depreciation of the home currency.

Since the object of the paper is to study the stabilization properties of floating exchange rates, only periods of floating exchange rate regimes are included in the bivariate VAR models. Table 1 shows the sample periods for the five countries. Sweden has only had a floating exchange rates for 11 years, which is too short a sample for estimating long-run equilibrium relationships (cointegrating vectors). We therefore estimate the cointegrating vectors for a much longer sample period (1960:1 to 2004) and impose these estimates on the VAR estimated on the sample 1993 to 2004 given the assumption that the long-run equilibrium relationship between exchange rates and fundamental variables is constant over time and unaffected by the exchange rate regime.

## 3 Statistical models

We estimate otherwise identical VAR models with and without cointegration for each of our five small open economies. King, Plosser, Stock, and Watson (1991) and Warne (1993) develop a framework for imposing long run restrictions on the effects of shocks within a cointegrated VAR in order to identify structural shocks. This empirical strategy differs from the models used in most previous studies in this literature (such as Artis and Ehrmann (2000), Bjorneland (2004)) precisely in that cointegration or long run equilibrium relationships between e.g. the levels of the real exchange rate and the level



of relative real output is allowed.

We start with the following VAR:

$$\Delta x_t = \mu + \Pi x_{t-1} + \sum_{i=1}^P \Gamma_i \Delta x_{t-i} + e_t. \quad (1)$$

$x_t$  in (1) denoted the  $n$ -dimensional vector of time series,  $\Delta x_t$  is their first differences,  $\mu$  is the vector of intercepts (deterministic time trends),  $\Pi$  is a reduced rank matrix that can be written as  $\alpha\beta'$ , where  $\alpha$  is the vector of error correction terms and  $\beta$  are the cointegrating vectors.  $\Gamma_i$  are  $n \times P$  matrices containing the estimated effects of lagged variables and  $e_t$  are the reduced form disturbances. Note that (1) collapses into a standard VAR in first differences when the term  $\Pi x_{t-1}$  that contains the long run equilibrium relationships and the error correction terms governing the adjustment towards long run equilibrium is dropped in the non-cointegrated models.

The cointegrated VAR model in (1) can be re-written as a common trends model (see e.g. Stock and Watson (1988)):

$$x_t = x_0 + A\tau_t + \phi(L)v_t. \quad (2)$$

where

$$\tau_t = \mu + \tau_{t-1} + \varphi_t \quad (3)$$

$A\tau_t$  is the permanent component of and  $\phi(L)v_t$  is the transitory component. The number of cointegrating vectors  $r$  in (1) determines the number of independent stochastic trends  $k$  in the common trends model (2) as  $k = n - r$  or the number of variables in the system minus the number of cointegrating vectors.  $\tau_t$  are the  $k$  stochastic trends with the drifts  $\mu$  and the innovations  $\varphi_t$ . The loading matrix  $A$  determines how the variables in  $x_t$  are affected by

the stochastic trends. The permanent shocks in  $\varphi_t$  are allowed to enter into the transitory shocks  $v_t$ , whereby shocks to the stochastic trends also affect the "cycles" or short run dynamics of  $x_t$ . In order to individually identify the structural shocks, restrictions are imposed on the long run impact matrix  $A$ .  $k(k-1)/2$  restrictions are needed for exact identification.<sup>2</sup>

The vector  $x_t$  contains five variables: Domestic real output, foreign real output, the domestic price level, the foreign price level and the level of the nominal exchange rate. Given five variables that are all integrated of order one, the number of independent stochastic trends in the system is determined by the number of cointegrating vectors. If there is no cointegration among the variables, there are five independent stochastic trends and a VAR in first difference should be used. Without cointegration it is possible to identify (i) a foreign productivity (or supply) trend, (ii) a domestic productivity (or supply) trend (iii) a foreign demand (or nominal) trend (iv) a domestic demand (or nominal) trend (v) a nominal exchange rate trend. Hence, the absence of cointegration implies that the nominal exchange rate is independent of the other variables in the long run. In particular, it displays no long-run equilibrium relationship to either foreign and domestic price levels or foreign and domestic real GDP. This violates the notion of a long-run equilibrium exchange rate. In addition, there is ample evidence that real as well as nominal exchange rates are cointegrated with fundamental variables (see for instance Dutton and Strauss (1997), and Groen (2005)) and that this matters for the

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<sup>2</sup>With  $n$  variables,  $r$  cointegrating vectors and  $k$  common trends, there are  $nk$  parameters in the  $A$ -matrix. The cointegrating restrictions identify  $rk$  parameters. Rewriting  $A$  as  $A_0\pi$  and applying a Cholesky decomposition to  $\pi$  yields another  $k(k-1)/2$  parameters, hence leaving  $k(k-1)/2$  free parameters to be identified. As pointed out by Warne (1993), this does not imply a recursive structure of the influence of  $\tau_t$  on  $x_t$ . See Warne (1993) for a more detailed discussion of the number of restrictions needed for exact identification.

qualitative results from variance decompositions of exchange rates (Alexius (2005)).

The economic interpretation of the identifying restrictions is that foreign real GDP is driven solely by foreign productivity shocks in the long run, domestic real GDP is driven by foreign and domestic productivity, the foreign price level is driven by the two productivity trends and the foreign monetary trend, and the domestic price level is driven by the two productivity trends and the two monetary trends. Finally, the nominal exchange rate is affected by the two productivity trends, the two monetary trends as well as by its own stochastic trend. Because monetary neutrality pins down the nominal exchange rate in the long run given the real exchange rate and the two price levels, an independent stochastic trend in the nominal exchange rate is inconsistent with long run monetary neutrality. We hence have a strong prior in favour of at least one cointegrating vector. Allowing more than one long-run equilibrium relationship among the variables implies only one stochastic trend either on the supply side or the demand side. For instance domestic real GDP (or price level) could be driven solely by foreign productivity (or monetary policy) rather than also have its own trend. Because we believe that there are country specific productivity trends and monetary trends, we have a strong prior also against more than one cointegrating vector. Hence, this system is expected to contain exactly one cointegrating vector. However, we do not impose a cointegrating rank of one but investigate the empirical consequences of no cointegration as well as two cointegrating vectors.

Given that there is one cointegrating vector or long-run relationship among the variables, we are left with four independent stochastic trends: (i) a foreign productivity (or supply) trend, (ii) a domestic productivity (or supply) trend (iii) a foreign demand (or nominal) trend (iv) a domestic de-

mand (or nominal) trend). In this case, the fifth shock is a transitory shock to the long-run equilibrium relationship. It has no long-run effect on any of the variables. It is not necessary to label this transitory shock (although we think it has a natural interpretation as stationary exchange rate noise).

Again, the four structural shocks are identified by imposing restrictions on the long-run impact matrix. We assume that foreign real GDP is driven solely by foreign productivity shocks in the long run, domestic real GDP is driven by foreign and domestic productivity, the foreign price level is driven by the two productivity trends and the foreign monetary trend, and the domestic price level is driven by the two productivity trends and the two monetary trends. In contrast to the model without cointegration, the nominal exchange rate has no independent stochastic trend of its own. Instead, it is driven solely by foreign and domestic productivity and monetary trends in the (infinitely) long run. Alexius and Carlsson (2005) have demonstrated that this type of structural identification using restrictions on the long run effects of shocks produce sensible results in the sense that the e.g. productivity shocks obtained from such a procedure are highly correlated with other measures of productivity such as Solow residuals.

Identification in the non-cointegrated follows the standard procedure. The VAR in first differences is identical to (1) except that the  $\Pi$ -matrix containing the cointegrating vectors and the adjustment coefficients is equal to zero. We start with the VMA( $\infty$ ) form of the reduced form estimation

$$x_t = Z(L)e_t, \tag{4}$$

where  $Z(L)$  is the inverted lag polynomial from the reduced form estimation and  $e_t$  denotes the reduced form residuals. Then, assume that the structural form VMA( $\infty$ ) can be written as

$$x_t = C(L)\varepsilon_t, \quad (5)$$

where  $C(L)$  is the structural counterpart to  $Z(L)$  above and  $\varepsilon_t$  are the structural shocks. Equating the two representations of the system in (4) and (5) and manipulating we get

$$C(1) = Z(1)C_0, \quad (6)$$

where  $C(1)$  is the long-run VMA impact matrix of the structural shocks,  $Z(1)$  the estimated VMA( $\infty$ ) from the reduced form estimation stage and  $C_0$  the short-run matrix defining the reduced form shocks as linear combinations of the structural shocks. This short run impact matrix is all we need for further analysis through impulse response functions and forecast error variance decompositions since it traces out the effects of structural shocks to the variables. Given the ordering of the variables  $(y^*, y, p^*, p, e)$ , the structural shocks are identified by assuming the the long-run impact matrix  $C(1)$  is lower triangular. Because there are five independent stochastic trends in the absence of cointegration, the nominal exchange rate contains it own trend or I(1) component rather than being tied down to a long run equilibrium level given by the stochastic trends in domestic and foreign prices and real output. This is the only important difference between the identification of structural shocks in the cointegrated and non-cointegrated models. For instance, foreign supply or productivity shocks is still identified as the sole driving force behind permanent movements. Domestic real output is driven by domestic as well as foreign supply shocks, while foreign demand shocks have permanent effects on foreign and domestic price levels but only temporary effects on real output. Domestic demand shocks in turn are separated from foreign demand shocks using the small open economy assumption that

the foreign price level is unaffected by domestic demand shocks in the long run. A monetary policy shock in the small country is defined as a demand shock as it has a permanent effect on domestic prices through a temporary effect on inflation but does not affect real output in the long run.

## 4 Empirical results

Estimating a common trends model requires several steps. First the appropriate number of lags in the VAR is determined using information criteria and residual misspecification tests. Above all, it is important that the number of lags is sufficiently high to remove residual autocorrelation since it creates biased estimates in autoregressive models. The preferred number of lags appear in the final column of Table 2. At this lag order, the residuals pass LM tests for first and fourth order autocorrelation and Portmanteau tests for higher order autocorrelation. According to the Engle (1982) test, the residuals do not display heteroscedasticity but there is some indication of non-normality as multivariate normality tests reject the null in two cases. However, since univariate Jarque-Bera tests do not reject that each residual series is normally distributed, non-normality does not appear to be a serious problem.

Second, the number of cointegrating vectors or the rank of  $\Pi$  in (1) is estimated using the Johansen (1988) maximum likelihood procedure. The test statistics are shown in Table 2. Both the  $\lambda_{\max}$  and the trace statistics indicate a single cointegrating vector among the five variables in four of the five cases. However, there appears to be two cointegrating vectors in the case of New Zealand.

In the case of Sweden, we only have ten years of data with a floating

exchange rate. This is a short sample for estimating the long-run properties of the data. As the long-run behavior of real exchange rates can be assumed to be independent of the exchange rate regimes, we estimate the long-run model (the  $\Pi$ -matrix in (1), i.e. the cointegrating rank and the cointegrating vectors) using the full sample 1960:1 to 2003:4. As shown in Table 2, the tests indicate one cointegrating vector (although a second is possible for some choices of lag length and using 90 percent asymptotic critical values).

Several economically interesting hypotheses can be investigated within this framework. Purchasing power parity can be expressed as a linear restriction on the cointegrating vector(s). This hypothesis that the vector belongs to the cointegrating space is rejected in all five cases. Monetary neutrality can also be expressed as a linear restriction on the cointegrating vector. Here, it implies that the real (as opposed to the nominal) exchange rate enters into the long-run equilibrium relationship with foreign and domestic real output. This is convenient because it allows us to separate monetary shocks from real shocks. If the coefficients on the nominal exchange rate and the two price levels differ from  $(1, -1, 1)$ , nominal shocks to foreign or domestic price levels may affect real output in the long run.

The structural identification of the shocks actually hinges on the assumption of long run monetary neutrality. If money is not neutral in the long run, nominal demand shocks affect real exchange rates which affect the level of GDP in the long run. Because our identification assumes that the development of real output in the long run is driven solely by productivity shocks, it requires long run monetary neutrality. New Zealand is a problematic case since there appears to be two cointegrating vectors and long run monetary neutrality is rejected both assuming one and two cointegrating vectors. We try two different solutions to this problem. First, as in Jacobson (2001),

we assume that there is one cointegrating vector characterized by monetary neutrality and proceed as in the other cases. Because the tests are known to be oversized in small samples (see for instance Jacobson (2001) and the references therein), this is a reasonable assumption. Second, we stick to the cointegrating rank of two and the unrestricted estimates of the cointegrating vectors. In the latter case the shocks cannot be given a structural identification but some of the issues can nevertheless be illuminated.

In the remaining four cases monetary neutrality is not rejected. Test statistics and  $p$ -values are reported in Table 3. We hence estimate common trends models under the assumption of a single cointegrating vector characterized by long run monetary neutrality or a long run equilibrium real exchange rate as function of domestic and foreign real output. The point estimates of the cointegrating vectors appear in Table 3. They have the expected signs in all cases except New Zealand, i.e. higher domestic productivity as proxied by the level of real output is associated with a stronger real exchange rate in the long run. Several of the point estimates are implausibly large in absolute values, which prompts us to investigate also alternative estimators of the cointegrating vector in Section 5 below.

Estimation of the VAR in first differences without cointegration is straight forward. Details can be found in Alexius and Post (2005).

#### **4.1 Are exchange rates responding to shocks or creating shocks?**

A major issue in the debate about whether floating exchange rates are stabilizing or destabilizing concerns the extent to which exchange rate movements constitute responses to fundamental disturbances such as shocks to supply and demand. of a monetary union typically argue that because a floating



exchange rate is subject to non-fundamental speculative movements, it creates additional variability rather than reducing it by shielding the economy from fundamental shocks. Variance decompositions from a VAR shed light on this issue as they can be used to quantify how much of the forecast error variance is due to different structural shocks. Thus if most movements are due to exchange rate shocks, we interpret this as evidence of destabilizing behavior or shock creation, while evidence that exchange rate movements are mainly responses to fundamental shocks indicates stabilizing behavior or shock absorption.

Table 4 shows the share of the forecast error variance decompositions due to exchange rate shocks at 1-40 quarter horizons for the VAR models with and without cointegration. Hence the remaining exchange rate movements are due to foreign and domestic supply and demand shocks. The results reveal that the influence of exchange rate noise is much smaller at all horizons in the cointegrated models than in the models without long run equilibrium relationships. The four fundamental shocks account for at least twice as much of the movements in exchange rates in the cointegrated models as in the models without cointegration and this ratio is frequently approaching ten.

A second observation from Table 4 is that the four fundamental shocks on average account for 93 percent of the ten-year forecast error variance in the models with cointegration, compared to only 48 percent without cointegration. Hence virtually all long run variation in nominal exchange rates is due to movements in the fundamental variables once we allow for the existence of long run equilibrium relationships between the level of the exchange rate on one hand and prices and real output on the other hand, which is a remarkable result. To our knowledge this is the first investigation of the effects of

fundamental variables on nominal exchange rates using cointegrated VARs. Similar studies of the sources of variation in *real* exchange rates have documented considerably smaller effects of fundamental variables.<sup>3</sup> For instance, the average share of the five-year forecast error variance decomposition of real exchange rates using a similar cointegrated specification is 55 percent in Alexius (2005). Her results in turn indicate a much larger influence of fundamental variables than what has been found in previous studies using VAR models without cointegration. The results in Table 4 for the models without cointegration are similar to previous findings (cf. Artis and Ehrmann (2000)).

## 4.2 Does exchange rate noise affect output and inflation?

A certain fraction of the movements in floating exchange rates is characterized as exchange rate noise in all our empirical models. This non-fundamental variability can be considered destabilizing only to the extent that it has considerable effects on output and inflation. If exchange rate noise only has negligible effects on output and inflation, a floating exchange rate could be more appropriately characterized as disconnected from the rest of the economy rather than actually destabilizing. One building block of the exchange rate disconnect puzzle discussed by Obstfeld and Rogoff (2000) is the obser-

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<sup>3</sup>Similar variance decompositions of exchange rate are also used to analyze questions about the relative importance of changes in the equilibrium exchange rate versus out-of-equilibrium movements. The study by Clarida and Galí (1994) belongs to this literature. It differs from our investigation of the sources of exchange rate movements in that they study real rather than nominal exchange rates and do not use cointegration. Clarida and Galí (1994) conclude that most movements in real exchange rates are caused by real demand shocks. Subsequent research has largely confirmed their findings.

vation while exchange rate variability has increased dramatically since the break down of fixed exchange rate systems, this variability has apparently not been translated into increased variability of output and inflation. Duarte (2005) and others discuss potential reasons for this disconnection of exchange rate from the rest of the macroeconomy. Again, the output from a VAR is well suited for investigating the extent to which exchange rate noise affects other variables. Impulse responses of output and inflation to exchange rate shocks as well as the share of exchange rate shocks in the variance decompositions of output and inflation provide detailed information about the quantitative effects.

Table 5 shows the forecast error variance decompositions of output and inflation in the four countries at the three and five horizons, i.e. the business cycle frequencies. First, exchange rate noise account for three to five times as much of the variance of both output and inflation in the cointegrated models as in the non-cointegrated models. This results is slightly puzzling in light of Table 4 which show that exchange rate shocks are much more important in the specifications without cointegration. Hence, even though exchange rate noise accounts for a larger share of exchange rate movements in the non-cointegrated model, the estimated effects of this noise on output and inflation are much larger with cointegration. The average share of output (inflation) fluctuations at the three-year horizon is only 6.2 (3.0) percent in the models without cointegration. The corresponding numbers from the cointegrated specifications are 22.6 (18.8).

Hence it is clear that the exchange rate noise captured by the cointegrated model affects output and inflation much more than the exchange rate noise captured by the non-cointegrated model, even though it is much more important source of movements in the nominal exchange rate in the latter

specifications. These exchange rate shocks have a clear interpretation in the cointegrated models - they constitute deviations from long run equilibrium. In the models without cointegration, exchange rate noise can loosely be understood as exchange rate movements that do not have permanent effects on price levels or real output. While the cointegrated and non-cointegrated VAR models capture very similar foreign productivity shocks for all five countries, the exchange rate shocks extracted by the two models are significantly correlated with each other only in one case.<sup>4</sup> Given that the true exchange rate shocks are unobservable, we cannot determine to what extent they affect output and inflation and it is not possible to interpret these results in terms of what model captures exchange rate noise better or more correctly.

Impulse responses of output and inflation to exchange rate shocks could potentially shed additional light on this issue. However, all impulse response from the models without cointegration are insignificant even at the 50 percent level using bootstrapped confidence intervals. Slightly more than half of them have the expected signs, i.e. output and inflation increase in response to an exchange rate depreciation. Corresponding impulse response function from the cointegrated models are significant and of the expected signs only marginally more often. Hence evidence from these impulse responses support the exchange rate disconnect view rather than support either the stabilizing or destabilizing role of floating exchange rates. Furthermore there is no clear distinction between the results from the models with and without cointegration in this particular aspect.

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<sup>4</sup>The average correlation between foreign productivity shocks in the cointegrated and non-cointegrated VARs is 0.86 and all individual correlation coefficients are highly significant. In case of the exchange rate shocks the average correlation is only 0.21 and only one out of five correlation coefficients is significant at the five percent level.

### **4.3 Do exchange rates stabilize asymmetric demand shocks on impact?**

The final issue to be analyzed using output from the VAR models is how the nominal exchange rate responds to an asymmetric demand shock on impact. If domestic demand falls in the small open economy but not abroad, an exchange rate depreciation stabilizes both inflation and output. Because domestic goods becomes cheaper relative to foreign goods, both foreign and domestic demand for domestic good increases. Hence, exchange rates perform a stabilizing function in the economy if they appreciate in response to asymmetric increases in demand. The predictions are less clear-cut in the case of asymmetric supply shocks. Because output and inflation move in different directions, the exchange rate (or monetary policy) cannot stabilize both variables simultaneously. If the exchange rate appreciates in response to an asymmetric increase in domestic supply, it stabilizes output, whereas it stabilizes inflation if it depreciates. Information about the response of the nominal exchange rate to asymmetric supply shocks hence contains information about whether the exchange rate stabilizes output or inflation rather than whether it is stabilizing or destabilizing.

The impulse response function of nominal exchange rates to (positive) asymmetric demand shocks in the five small open economies with and without cointegration are shown in Figures 1a to 1j. The dotted lines are 95 percent confidence intervals (asymptotic not bootstrapped). There is little evidence of stabilizing movements. The Swedish and Canadian exchange rates appreciate significantly (even using asymptotic standard errors that are known to be large) in response to an asymmetric demand shock, i.e. behave in a stabilizing manner in the models without cointegration. With cointegration, this is only true for the Canadian exchange rate. Hence allow-

ing for cointegration does not yield qualitatively different results in terms of the signs and significance of impulse responses of nominal exchange rates to asymmetric demand shocks. If anything, the results with cointegration indicate that exchange rate behavior is less stabilizing than the results without cointegration. As cointegration specifies long run equilibria for real exchange rates, it is not surprising that there is a tendency for nominal exchange rates to depreciate in response to an increase in domestic nominal demand as it will result in a higher price level. For the real exchange rate to return to equilibrium in the long run, the nominal exchange rate has to depreciate.

Although there are only minor differences between the cointegrated and non-cointegrated models concerning the signs of the impulse response functions, there is a striking difference between the two sets of models in terms of the length of the dynamic adjustment process. All impulse response functions from the VAR models in first differences are characterized by movements in the first quarters only. Thereafter, the impulse responses die out quickly. In contrast, impulse response functions from the cointegrated models display continued adjustment towards the new long run equilibrium for a much longer period of time, 20 quarters rather than just five to six. This adjustment is contained in the term  $\alpha\beta'x_{t-1}$  in equation (1), where  $\alpha$  is the error correction term, expected to be negative in order to push e.g. the exchange rate down if it is above long run equilibrium and  $\beta'x_{t-1}$  is the deviation from long run equilibrium in the previous period. The contrast between the two sets of impulse responses with and without cointegration can be interpreted as evidence that this term remains large also several years after a shock has occurred.

## 5 Robustness of the results

A number of the specific characteristics of the empirical specification are not obviously just one optimal choice. For instance, point estimates of the cointegrating vectors can be obtained using a variety of methods. Several studies have indicated that the Johansen point estimates tend to be larger in absolute values than alternative estimates. Indeed, all of our point estimates are above 2 in absolute numbers, while stylized facts indicate that the magnitude of the effect is around 0.7. Choosing the number of lags in the VAR has been called "art not science". To what extent do such choices influence the qualitative results from an investigation such as this one? In order to study the robustness of the results with respect to credible variations of the empirical specification we re-run the main results using alternative methods to estimate the cointegrating vectors and alternative choices of lag length. Our impression is that fundamental variables appear to have larger influence on exchange rates the more interaction between exchange rates and the fundamental variables the model contains. Since specifications with larger point estimates of the cointegrating vectors and more lags in the VAR contain more such interaction, we expect these empirical models to result in larger shares of the variance decompositions due to fundamental shocks and hence less non-fundamental variation of nominal exchange rates.

### 5.1 Alternative estimates of the cointegrating vectors

The point estimates of the cointegrating vectors or long-term equilibrium relationships between the levels of exchange rates, prices and output can be obtained using a variety of methods. Due to the prevalence of multiple cointegrating vectors, the Johansen procedure is a natural choice. However,

the Johansen point estimates are well known to be larger than alternative estimates. For instance, the effects of relative productivity growth on real exchange rates is frequently found to be less than unity. Using Johansen, all point estimates are above unity and several of them are above four. This could affect the results by (possibly greatly) exaggerating the effects of fundamental variables on exchange rates. We therefore re-estimate the common trends models using cointegrating vectors estimates using dynamic OLS as suggested by rather than Johansen. As shown in Table 6 these alternative estimates are of much smaller magnitudes than the original Johansen estimates. Only a single DOLS point estimate exceeds two in absolute value, while every single Johansen estimate is above 2.0 and four of ten are larger than ten. Given that stylized facts concerning the magnitude of the effect of relative productivity on real exchange rates lies between 0.2 and 0.8,<sup>5</sup> the Johansen estimates are implausibly large. Strauss (1996) also estimates these coefficients using Johansen and obtains point estimates between 1.21 and 13.97. Similar results in terms of implausibly large estimates of the Balassa Samuelsson effect using the Johansen procedure are obtained by Kakkar (1996)<sup>6</sup>.

Table 7 contains the share of the forecast error variance decompositions due to non-fundamental shocks using cointegrating vectors estimated by Johansen and DOLS. We want to know whether using a particular method systematically affects the results. It turns out that fundamental variables have stronger effects on exchange rates when the larger Johansen estimates of the long-run equilibrium relationships are used than with the smaller DOLS

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<sup>5</sup>These numbers are taken from Chinn (1997), who surveys the empirical literature.

<sup>6</sup>A revised version of the latter paper is published as "Capital-Labor Ratios and Total Factor Productivity in the Balassa-Samuelson Model" in the Review of International Economics, 2002. However, the results in question do not appear in this version.



estimates. The variance decompositions of all five countries move in this direction and the average difference between the share of the ten-year FEVD due to exchange rate shocks for the two methods is 15.3 percent. The main result that most long run movements in nominal exchange rates are caused by fundamental shocks once cointegration is allowed is nevertheless robust to the choice of estimation method.

## 5.2 Alternative choices of lag length

In the same manner as large point estimates of the coefficients in the cointegrating vectors may exaggerate the interaction between exchange rates and fundamental variables, including more lags in the VAR could result in stronger influence of supply and demand shocks on exchange rates. For instance, the results of Joyce and Kamas (2003) suggest that the share of the forecast error variance due to exchange rate shocks systematically decrease and the share due to fundamental demand and supply shocks increase with the number of lags in the VARs. To investigate this issue we re-estimate the models with several additional lags and analyze the results. In particular, we study whether the qualitative conclusions concerning the relative importance of fundamental economic shocks versus exchange rate noise in the variance decompositions are affected by this. The cointegrating vectors are re-estimated for the alternative choices of lag length but we have not altered the cointegrating rank in the two cases where the tests start indicating more than one cointegrating vectors as two more lags are added to the VAR. The results are shown in Table 8. In three of the five cases, the models with more lags indicate larger influence of fundamental variables on exchange rates. Evidence from the two remaining countries is inconclusive as fundamental variables are more important at some horizons and less im-

portant at other horizons. The average share of fundamental variables in the ten-year variance decomposition increases by 11.9, which is considerably less than the qualitative effects of moving from Johansen estimates of the cointegrating vectors to DOLS estimates. Thus including more lags in the VAR within a reasonable range in the sense that at least one information criterion indicates this choice tends to increase the influence of fundamental variables on exchange rates as indicated by variance decompositions. This is however not a monotonous relationship. If the number of lags is increased beyond reasonable choices, for instance by adding two more lags than in Table 8, the share of fundamental shocks in the variance decompositions typically falls.

## 6 Conclusion

VAR models produce several types of output that can be used to evaluate the stabilizing properties of floating exchange rates. Variance decompositions show how much of the movements of exchange rates that are responses to fundamental shocks and how much that is non-fundamental noise. They can also be employed to determine the extent to which exchange rate noise affects output and inflation. Exchange rate variability is clearly less destabilizing the smaller the effects on the rest of the economy. Impulse responses are useful because we can detect whether the nominal exchange rate moves in a stabilizing direction as the economy is hit by shocks. This paper investigates whether the qualitative results concerning the stabilizing role of exchange rates from structural VAR differs depending on whether long-run equilibrium relationships between the variables is included or excluded from the empirical specification. We estimate identical VARs with and without cointegration and compare the results.

The main difference between the results from cointegrated and non-cointegrated VAR models is found in the forecast error variance decompositions, especially at long horizons. The cointegrated models indicate that virtually all long run movements in nominal exchange rates are due to movements in the fundamental variables. The average share of the ten-year forecast error variance attributable to non-fundamental exchange rate noise is 93 percent, compared to only 42 percent in the models without cointegration. Corresponding results for real exchange rates imply considerably lower numbers (55 percent on average in Alexius (2005)). Hence if long run equilibrium relationships between the level of the nominal exchange rate on one hand and nominal price levels and domestic and foreign real output on the other are taken into account, nominal exchange rates are almost completely determined by movements in these other fundamental variables in the long run.

Impulse responses indicate that nominal exchange rates display little tendency to stabilize asymmetric demand shocks on impact. The signs and significance of the impulse response functions differ little between the cointegrated and non-cointegrated models. If anything, the cointegrated models show less stabilization on impact, presumably because the existence of a long run equilibrium real exchange rate tends to induce a depreciation of the nominal exchange rate in the long run as domestic prices increase in response to the demand shock. There is however a clear difference in the dynamic adjustment in response to shocks. Impulse response functions from the VARs in first differences die out much quicker than the corresponding paths from cointegrated VARs. The former display almost no movements at all beyond the first 4-6 quarters, whereas the latter continue to adjust to the long run equilibrium for up to ten years.

While the VAR models with and without cointegration capture almost

identical foreign supply shocks in every case, the exchange rate shocks identified by the two specifications show little resemblance to each other. The exchange rate shocks from the cointegrated models account for much larger shares of the variances of output and inflation than the exchange rate shocks from the VARs in first differences. However, because true exchange rate shocks are unobservable we cannot evaluate which model is more correct in this respect.

Robustness tests indicate that empirical specifications featuring cointegrating vectors estimated using the Johansen procedure that tend to result in large point estimates and empirical specifications with a high but still reasonable number of lags tend to indicate stronger influence of fundamental variables on exchange rates. Hence, the empirical specification that yields the largest influence of fundamental variables on nominal exchange rates appears to be a cointegrated model where the cointegrating vectors are estimated using the Johansen procedure which frequently results in point estimates of large absolute magnitudes and including a slightly higher number of lags than the optimal choice.

The main conclusion from the investigation is that there are large and important differences between the evidence of the stabilizing properties of floating nominal exchange rate depending on whether long run equilibrium relationships between the levels of the variables are included in the empirical models or not. Because most studies do not include cointegration, the evidence that exchange rates are destabilizing rather than stabilizing may have to be reconsidered. In particular, we find that almost all long run movements in nominal exchange rates are due to fundamental demand and supply shocks when cointegration is allowed.

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## Tables

Table 1: Sample periods and inflation target periods

Country	Sample period
Australia (AUS)	1983q1-2004q2
Canada (CAN)	1970q2-2004q1
New Zealand (NZL)	1985q1-2003q4
Sweden (SWE)	1993q1-2004q2
Switzerland (CHE)	1980q1-2004q2

The floating exchange rate period for Switzerland starts in 1973 but data is only available from 1980.

Table 2: The Johansen (1988) tests for cointegrating rank

Country	$\lambda(1)$	$\lambda(2)$	$\lambda(3)$	$\lambda(4)$	$\lambda(5)$	$tr(1)$	$tr(2)$	$tr(3)$	$tr(4)$	$tr(5)$
Australia	42.29	18.60	13.79	4.71	1.44	80.84	38.55	19.95	6.16	1.44
Canada	38.94	23.31	17.99	6.42	2.56	89.22	50.28	23.97	8.99	2.56
New Zealand	52.37	33.55	18.64	5.26	1.01	110.83	58.47	24.92	6.27	1.01
Switzerland	30.14	22.98	15.85	10.15	0.28	79.40	49.26	26.28	10.43	0.28
Sweden	54.31	23.90	13.82	4.04	0.83	96.89	42.58	18.68	4.86	0.83
C. V.	30.90	24.73	18.60	12.07	2.69	64.84	43.95	26.79	13.33	2.69

The row labelled C. V. contains 90-percent critical values taken from Osterwald and Lenum (1992). Two lags in the VARs.



Table 3: Tests of monetary neutrality and parameter estimates

Country	<i>LR</i> -test	<i>p</i> -value	<i>y</i> *	<i>y</i>
Australia	5.87	0.05	-17.062	-26.914
Canada	3.76	0.15	-3.311	2.277
New Zealand	10.90	0.00	10.356	-20.719
Switzerland	4.67	0.10	-10.313	20.568
Sweden	4.07	0.13	-4.888	6.585

The likelihood ratio test for monetary neutrality is a test of whether the single cointegrating vector differs significantly from  $(\beta_1, \beta_2, 1, -1, 1)$  given the order of the variables ( $y^*$ ,  $p^*$ ,  $y$ ,  $p$ ,  $e$ ). The test statistics is  $\chi^2(2)$  distributed. The final two columns contain the estimated coefficients on  $y$  and  $y^*$  in the cointegrated vectors given monetary neutrality.

Table 4: The importance of exchange rate noise and cointegration

Horizon	CI	1	4	12	40
Australia	Yes	13.1	11.5	8.7	5.8
	No	61.3	57.4	50.1	47.9
Canada	Yes	36.7	25.5	23.8	15.8
	No	82.8	79.0	65.4	63.7
New Zealand	Yes	20.4	19.9	7.9	1.6
	No	41.3	40.9	35.6	34.8
Switzerland	Yes	11.0	8.1	7.1	7.0
	No	72.2	69.4	65.7	64.5
Sweden	Yes	26.0	29.8	10.1	4.5
	No	69.1	63.5	58.3	50.4

The shares of the forecast error variance decompositions of nominal exchange rates due to exchange rate shocks in the cointegrated and non-cointegrated models at different horizons. Hence the four fundamental shocks account for the remaining variance.

Table 5: Shares of variance decompositions of inflation and output due to exchange rate shocks

Horizon	CI	$\pi$		$y$	
		12	20	12	20
Australia	Yes	12.8	15.5	16.1	13.3
	No	6.1	6.1	7.7	7.7
Canada	Yes	21.7	17.9	19.4	16.5
	No	6.8	6.8	4.5	4.5
New Zealand	Yes	17.6	14.9	22.7	13.3
	No	4.9	4.9	8.0	8.0
Switzerland	Yes	31.1	24.6	20.4	18.0
	No	4.6	4.6	5.3	5.3
Sweden	Yes	29.9	29.6	15.5	16.6
	No	3.1	3.1	8.4	8.4

The rows labelled CI Yes and CI No contain the results from the models with and without cointegration.

Table 6: Estimates of the cointegrating vectors - Johansen vs. DOLS

Method	Johansen		DOLS	
	$y^*$	$y$	$y^*$	$y$
Australia	-17.062	26.914	-0.229	1.734
Canada	-3.311	2.277	-1.375	1.621
New Zealand	-20.719	10.356	0.586	1.724
Switzerland	-10.313	20.568	-0.977	2.688
Sweden	-4.888	6.585	-1.084	1.423

Point estimates of the parameters in the cointegrating vectors given monetary neutrality (i.e. unity parameters on the two price levels).

Table 7: Importance of exchange rate shocks given different methods for estimating the cointegrating vectors

Country	Method	Horizon			
		1	4	12	40
Australia	J	13.1	11.5	8.7	5.8
	DOLS	22.6	19.4	17.7	13.1
Canada	J	36.7	25.5	23.8	15.8
	DOLS	33.4	21.4	8.9	8.8
New Zealand	J	20.4	19.9	7.9	1.6
	DOLS	38.4	38.7	37.6	33.5
Switzerland	J	11.0	8.1	7.1	7.0
	DOLS	46.2	58.9	52.9	32.4
Sweden	J	26.0	29.8	10.1	4.5
	DOLS	31.0	41.0	39.0	23.3

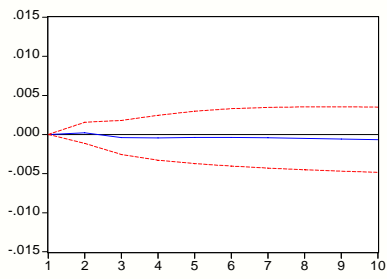
The rows labelled J contain the shares of the forecast error variance decompositions due to exchange rate noise when the cointegrating vectors are estimated using the Johansen method. The rows labelled DOLS contain corresponding results using DOLS.

Table 8: Importance of exchange rate noise given two additional lags in the VARs

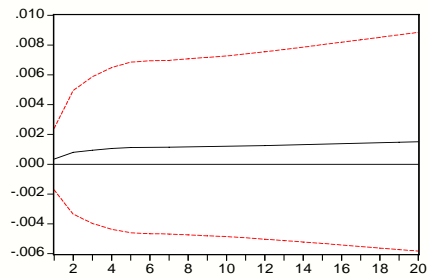
Horizon	1	4	12	40
Australia	31.9	30.0	22.7	19.4
Canada	37.4	28.0	11.5	8.7
New Zealand	33.5	25.8	23.2	17.5
Switzerland	27.4	21.2	7.2	2.3
Sweden	16.2	9.8	9.6	3.7

The share of the forecast error variance decompositions due to exchange rate noise at different horizons.

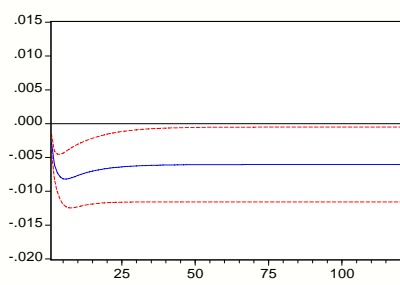
Australia - no cointegration



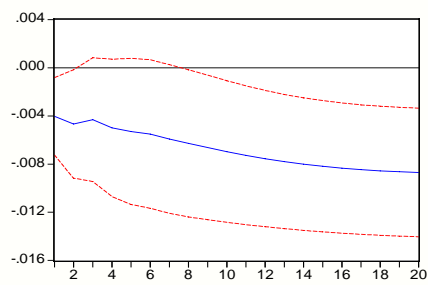
Australia - with cointegration



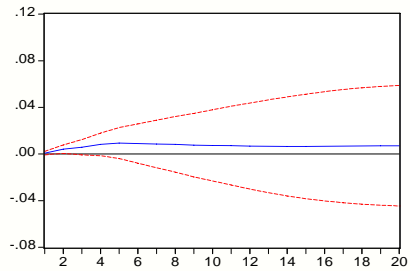
Canada - no cointegration



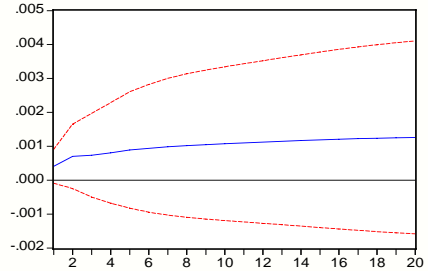
Canada - with cointegration



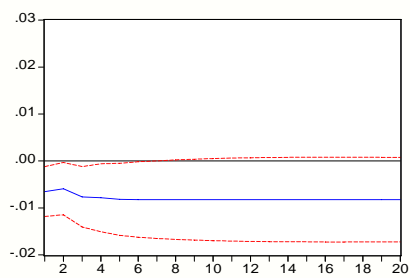
New Zealand - no cointegration



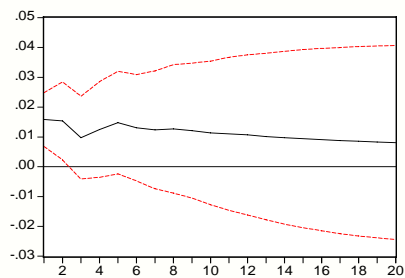
New Zealand - with cointegration



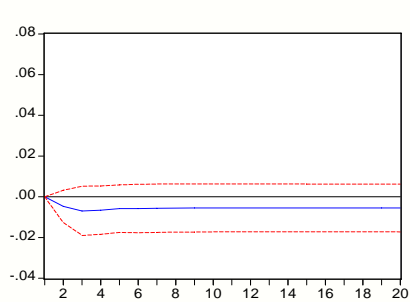
Sweden - no cointegration



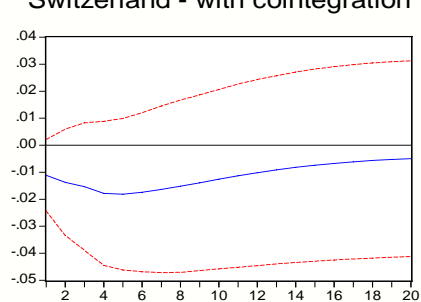
Sweden - with cointegration



Switzerland - no cointegration



Switzerland - with cointegration



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