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wissenschaften und Statistik

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THEORY-BASED MEASUREMENT OF THE SAVING-INVESTMENT CORRELATION

WITH AN APPLICATION TO NORWAY

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Serie II - Nr. 205

Mai 1993

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Abstract

We demonstrate that the correlation of saving and investment is measured best by an error correction model (ECM), because theory implies a cointegrating relation between these variables. The ECM comprises all previous specifications as special cases, which are shown to be potentially misspecified on theoretical grounds. We argue that the correlation can serve to reject the hypothesis of capital immobility, but not the one of capital mobility. Applying the ECM to Norway yields the following findings: First, the ECM outperforms prevailing specifications. Second, we detect structural breaks, which underpins the need for careful diagnostic testing and, third, the correlation's time profile is consistent with other indicators of capital mobility. The Feldstein–Horioka puzzle does not exist for Norway.

[JEL Classification: E21, E22, F21, F32, F41]

1 Introduction

The findings of Feldstein and Horioka (1980) have led to numerous theoretical and empirical papers on the close correlation between domestic saving and domestic investment and its supposed implications for international capital mobility. Feldstein and Horioka (1980: 317) state that "with perfect world capital mobility, there should be no relation between domestic saving and domestic investment: saving in each country responds to the worldwide opportunities for investment while investment in that country is financed by the worldwide pool of capital." However, in a cross-country regression using period–averaged saving and investment figures for 16 OECD countries, they obtain a significant coefficient close to unity and conclude that capital is rather immobile. This result constitutes the "Feldstein–Horioka puzzle", as it contradicts the widely held perception that capital is highly mobile across countries. Subsequent empirical work confirmed the close correlation, though its implication for the degree of capital mobility is a moot point (see Tesar 1991).

This paper contributes to the understanding of the puzzle on both theoretical and empirical counts. First, we present a theory–based econometric specification for estimating saving investment correlations. Second, we discuss the possible usefulness of the estimates for detecting capital mobility. Third, we provide empirical results for the interesting case of Norway.

Our research is motivated by the observation that various regression equations have been used to measure the saving investment correlation, but that none of them has a firm theoretical foundation. This in turn raises questions about the interpretation and comparability of the existing empirical results. In order to obtain reliable estimates of the saving investment correlation, we propose an econometric specification that is founded in intertemporal general equilibrium models, in which agents optimize under intertemporal budget constraints. We are then able to show that studies reporting time–series regressions have estimated misspecified equations and that studies reporting cross–section regressions are seriously flawed because they neglect dynamics. As a result the puzzle may turn out to be an artifact caused by measurement errors. However, the significance of reliable measurement of the saving investment correlation goes beyond solving the "Feldstein–Horioka puzzle". Since current account dynamics are at the heart of open economy models, saving investment correlations represent the stylized facts these models are to explain.

Norway serves as a suitable example to cement our methodological arguments with empirical evidence, thanks to its system of capital controls, which were phased out during the 1970s to 1980s, the oil discoveries and its small size. We demonstrate that the failure to

take structural breaks into account seriously distorts the picture, making a strong case for careful diagnostic testing. Our main empirical result is that the "Feldstein–Horioka puzzle" does not exist for Norway.

The paper proceeds as follows. In section 2 we briefly summarize the state of the discussion regarding Feldstein and Horioka's findings and interpretations. Section 3 is devoted to methodology: We derive our specification from the theory and compare it to the specifications previously used. We also discuss how to make inferences about capital mobility. In section 4 we sketch major events in the post-war Norwegian economic history, notably the abolition of capital controls and the emergence of the important oil sector. Section 5 delivers the empirical results, while in section 6 we attempt to assess the influence of the oil sector on the estimates. Section 7 summarizes and concludes.

2 "The Feldstein–Horioka Puzzle"

Many authors have confirmed Feldstein and Horioka's result of a high and stable correlation of saving and investment for OECD countries, both in cross–country studies and in time–series studies. This finding can be regarded as a robust empirical regularity; smaller countries, especially less developed countries, tend to display lower correlations.[1]

These findings present us with three riddles. First, do the observed high correlations of saving and investment rates really indicate low capital mobility? Second, why do coefficients remain relatively stable until the mid-eighties, despite major deregulations of financial markets around 1974, for instance in the U.S., in Germany, and in the U.K.? Third, how can lower correlations for smaller countries be explained, although these countries tend to have stricter capital controls and less developed financial markets?

Several critiques of Feldstein and Horioka's interpretation have emerged that try to answer these questions. The point most frequently raised is the endogeneity of saving, implying that third factors can produce a substantial correlation of saving (S) and investment

[1] Cf. inter alia Fieleke (1982); Feldstein (1983); Penati and Dooley (1984); Summers (1985), Dooley et al. (1987), Bayoumi (1990), Feldstein and Bacchetta (1991), Tesar (1991) for cross-country analyses and Frankel (1986), Obstfeld (1986, 1989), Bayoumi (1990), Tesar (1991) for time–series studies. An exception is Frankel (1991), who obtains in a time-series regression for the U.S. a coefficient of 0.85 for the period 1930–79, while for 1980–87 it is 0.15, due to the large current account deficits in the eighties ("Reaganomics").
Murphy (1984), Obstfeld (1986), Dooley et al. (1987), Wong (1990) analyze correlations for smaller industrialized or developing countries.

(I) in the presence of full capital mobility.[2] This endogeneity problem can be tackled by averaging over longer periods to wash out business cycles, as Feldstein and Horioka (1980), Feldstein (1983), Tesar (1991) and others have done, or by adding the respective variable to the regression (Summers 1985, Feldstein and Bacchetta 1991), or by using instrument variables in a two stage least square regression, as done by Feldstein and Horioka (1980), Frankel (1986, 1991), Dooley et al. (1987). Yet, none of these procedures alters the results considerably.

A special form of endogeneity may arise from a governments' reaction to incipient current account imbalances; especially variations in public saving may be used to offset fluctuations of private saving (inter alia Fieleke 1982, Tobin 1983, Westphal 1983, Summers 1985, Bayoumi 1990). However, an identification problem arises: The observed negative relationship between budget deficits and the private saving–total investment gap can be attributed to either endogeneous government reactions with capital being highly mobile (Summers 1985), or to a crowding out effect of private investment by public borrowing, presupposing less than perfect capital mobility (Feldstein and Bacchetta 1991).

Another argument tries to reconcile the idea of high capital mobility with a high SI correlation: for large countries, an exogenous variation in domestic saving, say an increase, will feed back to an increase in investment demand via a lowered world interest rate (Murphy 1984). Moreover, larger countries tend to be more self-contained, and regional shocks may cancel out to a greater extent in larger entities (Harberger 1980, Tobin 1983). Yet, Frankel (1986) shows for the U.S. that the large country effect is far from being responsible for the high correlation.

Frankel (1986) and Dooley et al. (1987) have pointed out that for SI correlation close to zero the real interest rate parity must hold, a condition which is frequently violated.[3] The reason for this is the insufficient integration of goods markets, leading to non–zero currency premia; especially the ex ante purchasing power parities do not hold. However, since real interest rates move in tandem (though not one–to–one, see Cumby and Mishkin 1986), only the – smaller – *variations* of the real interest rate differentials matter, not the differentials as such.

Though these papers shed light on possible sources of positive SI correlations in the

[2]Among the factors mentioned are the procyclicality of S and I, population growth (Summers 1985, Obstfeld 1986), productivity and other shocks (e.g. Obstfeld 1986:74-82), and non–traded goods (Murphy 1986, Wong 1990).

[3]Cf. inter alia Cumby and Obstfeld (1984), Mishkin (1984a, 1984b), Mishkin (1988).

presence of full capital mobility, the basic questions wait to be answered. This remains true even though the correlation based on annual data has been found to be considerably lower and variable (Sinn 1992).

3 Measuring the Correlation of Saving and Investment: Methodological Issues

The regression of saving on investment looks into an unusual relation, because the regression equation cannot directly be derived from a theoretical model. It can neither be viewed as structural relationship (it is not a behavioral relation in a model) nor as a reduced form relation (it is not the solution of a system). Though there is no obvious candidate specification, surprisingly little attention has been devoted to the issue of specification. Instead, various econometric equations have been used to measure the supposedly same phenomenon without a systematic evaluation of their relative merits. The empirical literature provides correlations between the levels of S and I, between changes of S and I, and between the levels of S and I averaged over varying time–spans.

As will be demonstrated below, closer inspection of modern macroeconomic theory shows that the specifications used so far are incompatible with key theoretical insights. This incompatibility between theory and empirical practice has two consequences, which potentially invalidate the conclusions drawn from the existing empirical work. First, empirical estimates are probably biased due to misspecification. Second, it is not exactly clear, what we can infer from estimates which come from different specifications, because we lack a theoretical guideline telling us how to interprete and to compare them. For instance, are studies using period–averaged data in a cross-section as valuable for detecting capital mobility as studies using time–series data? Without theory it is hard to tell. We believe that the confusion about the merits of the SI correlation can at least partly be traced back to the mismatch of recent theoretical contributions and prevailing methods of measurement.

In this section we put forward a specification that *is* built upon modern macroeconomic theory and that is broad enough to cover opposing viewpoints concerning the factors producing the SI correlation. We then survey the econometric specifications used in the literature and show that they are special cases of our specification. Finally, we address the issue, what we can infer from the correlation for the degree of capital mobility.

3.1 Specification of the Regression Equation

Our theoretical frame of reference consists of the open-economy variants of the modern macroeconomic theory, as expounded in Blanchard and Fischer (1989). In both the infinitely-lived representative agent models and the overlapping generations models, agents maximize (expected) life-time utility subject to an intertemporal budget constraint. Capital is assumed to be completely mobile, and hence agents can use the international capital market for smoothing their consumption.

We consider intertemporal general equilibrium models with steady states in which the current account, when suitably scaled (e.g. by output), is constant. Accordingly, saving and investment have a one-to-one relationship in the steady state. An example is the equality of saving and investment, implying that sustained current account deficits or surpluses are ruled out. In the short run, however, shocks to the system may push the economy out of the steady state and cause saving and investment to temporarily diverge from their steady state values. These models are able to produce non-zero short–run SI correlations despite perfect capital mobility. Examples are Buiter (1981), Koch (1992), Persson and Svensson (1985), Obstfeld (1986), Matsuyama (1987) and Finn (1990).

The modern analysis also shows that both the sign and size of this endogenously produced SI correlation depend on the nature and the size of the shock and the structure of the economy (see esp. Finn 1990). The same holds for the level of saving and investment in the new steady state. For example, Matsuyama (1987) demonstrates in a finite horizon overlapping generations model that an increase in the oil price may lead to a current account surplus or deficit in the short run, depending on whether the older generations suffer disproportionately or not. Moreover, the real capital stock, and hence investment and saving, are unambiguously lower in the new steady state.

The characteristics sketched above have important implications for the econometric specification. First, since the steady state value of investment and saving depends on exogenous variables, which may be non-stationary, they may be non-stationary variables too. Second, the theory implies that saving and investment have a one-to-one relation in the steady state, regardless their value. In other words, saving and investment are co-integrated variables. Engle and Granger (1987) prove that variables that exhibit these two properties have an error correction representation. Stationary variables can also be described by an error correction model. Consequently, the saving investment regression should be specified as an error correction model (ECM).

The simplest member of this class of specifications, which already serves our purpose, is

$$\Delta IR_t = \alpha + \beta \Delta SR_t + \gamma(SR_{t-1} - IR_{t-1}) + \delta SR_{t-1} + \epsilon_t \tag{1}$$

where IR and SR denote the share in output of investment and saving, respectively, and ϵ is a well–behaved disturbance. The analytically relevant SI correlation is the short-run correlation, defined between the changes of saving and investment, as measured by the parameter β. The long-run relation between saving and investment can be derived as the steady state solution:

$$\alpha + \gamma(\bar{SR} - \bar{IR}) + \delta \bar{SR} = 0 \tag{2}$$

If $\delta = 0$, the current account $(\bar{SR} - \bar{IR})$ equals some constant in the long run, while if $\alpha = \delta = 0$, it is zero. In both cases there exists a one-to-one long-run relation, as theory implies. Testing parameter restrictions enables us to discern whether the steady state relations suggested by modern open macroeconomic models are consistent with the data.[4] An affirmative finding would lend support to our claim that an ECM reliably measures the saving investment correlation.

Our theoretical frame of reference is broad enough to encompass (in principle) all explanations for zero and non-zero SI correlations, including limited capital mobility, endogenous government behavior and real interest rate differentials. All explanations are consistent with the idea that in the long run the current account is constant and that saving investment dynamics are temporary phenomena. For example, Dooley et al. (1987) and Frankel (1991, 1992) assert that imperfectly integrated goods markets lie at the root of the positive SI correlation. Sluggish price adjustment creates the temporary real interest rate differentials, that are the driving force behind saving investment dynamics. The real interest rate differentials decline in the course of time, and the long-run equilibrium of a balanced or constant non-zero current account is eventually reached.[5] Consequently, an ECM should be used for measuring the saving investment correlation, no matter the prior beliefs about the interpretation of this correlation.

Some of the explanations for non-zero SI correlations have already been incorporated in the intertemporal general equilibrium framework. Bacchetta (1992) introduces capital controls and a regulated domestic financial sector into an open economy model a la Matsuyama

[4]Note that the requirement that dynamic equations be consistent with the long–run equilibrium originates from Davidson, Hendry, Srba and Yeo (1978), who introduced the influential error correction model.

[5]This is exactly what Modjtahedi (1988) finds in his study on real interest rate dynamics. His real interest differentials converge to a constant value after six months, which can be explained by stable tax differentials.

(1987) and investigates the consequences of liberalization and deregulation. The stochastic overlapping generations two country model (one small, one large country) in Finn (1990) generates, in spite of perfect capital mobility, differences in expected real rates of return across countries.

When modelling saving investment dynamics, care should be taken to detect structural breaks. It is a distinct possibility that different error correction models have governed the observed time series of saving and investment. Examples of events that may have caused structural breaks include the change in exchange rate regime, leading to higher exchange rate variability, which leads to real interest rate differentials (McKinnon 1987; Frankel and MacArthur 1988), reduction in capital controls and deregulation of domestic financial systems, large changes in the price of oil, sectoral shifts and increased openness of economies. These considerations demonstrate the crucial importance of diagnostic testing in order to detect structural breaks. Yet, the empirical literature devotes little attention to diagnostic testing.[6]

3.2 Review of Previous Specifications

Empirical work on the saving investment correlation has employed cross-section regressions as well as time-series regressions. The cross–section studies use as observations the saving and investment rates for each country, either for a particular year (Tesar 1991, Sinn 1992) or averaged over some multi–year period (Feldstein and Horioka (1980) and other studies). Their regression equations are misspecified because they invariably concern a static relationship between saving and investment, instead of an ECM, suggested by intertemporal general equilibrium models.[7] Moreover, the common practice of using period–averaged data makes the estimated SI correlation unfit for assessing the degree of capital mobility on theoretical grounds. Sinn (1992) raises this point arguing that the intertemporal budget constraint implies that saving and investment are approximately equal when averaged over long periods of time. His empirical analysis shows that averaging over decades creates an

[6] Feldstein (1983) and Feldstein and Bacchetta (1991) do not even report Durbin–Watson (DW) statistics. Bayoumi (1990) observes that satisfactory DW-statistics were found for most regressions. Frankel (1986, 1991), estimating regressions in levels, finds low DW-statistics. He proceeds by assuming first order autocorrelated errors, but does not adjust his dynamic specification. Vikøren (1991) reports a full set of diagnostic statistics.

[7] The regression equation is eq. (3) in the main text, with time index t replaced by country index i.

upward bias in the estimated SI correlation.[8]

The time-series studies estimate the SI correlation per country on the basis of time series, employing four different specifications. Frankel (1986, 1991) estimates the static equation

$$IR_t = \theta_0 + \theta_1 SR_t + \epsilon_t \ . \tag{3}$$

Because this specification ignores the dynamic adjustment process, it cannot adequately capture saving investment dynamics.

Feldstein (1983) and Bayoumi (1990) estimate the SI relation in first differences:

$$\Delta IR_t = \phi_0 + \phi_1 \Delta SR_t + \epsilon_t \ . \tag{4}$$

Although eq. (4) measures a short-run correlation, it has no static equilibrium solution in the sense that nothing is implied regarding the (relation of the) *levels* of saving and investment in the steady state. It is only correctly specified if there is indeed no long-run relationship between saving and investment. Since theory maintains the opposite, eq. (4) is misspecified – it is overdifferenced. The reason for Bayoumi (1990) to difference the time series was to make them stationary. However, Engle and Granger (1987) demonstrate that if saving and investment are co-integrated variables, eq. (4) is misspecified.

Feldstein and Bacchetta (1991) introduce a lagged adjustment of investment to changes in saving and posit that investment reacts to the gap between investment and saving in the previous period:

$$\Delta IR_t = \psi_0 + \psi_1 (SR_{t-1} - IR_{t-1}) + \epsilon_t \ . \tag{5}$$

This specification restricts the short-run correlation between IR_t and SR_t to be zero and thus imposes limitations on the dynamic structure. Since it seems rather dubious that the data justify this restriction, eq. (5) is also misspecified.

Summarizing, specifications (3) – (5) are all found wanting, and estimating them may result in unwarranted inferences. Note that eqs. (3) to (5) are contained in our ECM, eq. (1), as special cases enabling us to test the validity of the parameter restrictions in section 5.[9] Our theoretical framework also gives us clues as to what the parameter restrictions entail. The static equation (3) and the equation in differences (4), which is essentially

[8] Sinn derives his result in a non-growth framework. The drift of his argument still holds when there is growth. The time-invariance of the intertemporal budget constraint also offers an explanation why the estimated correlation in the cross-section studies has decreased only slowly over time.

[9] The restrictions are: $\beta - \delta = 1$, $\gamma = 1$ for (3), $\delta = \gamma = 0$ for (4), and $\delta = \beta = 0$ for (5).

static, are both compatible with theories which do not look on saving and investment as solutions of an intertemporal decision problem.

To our knowledge Vikøren (1991) is the first to apply an error correction model, discarding eqs. (4) and (5) as incompletely specified regression models. Using the model in Sachs (1981), he argues that the SI regression should distinguish between the long–run correlation, which reflects the intertemporal budget constraint, and the short–run correlation, which could serve as an indicator of capital mobility. However, his theoretical model describes an economy which exists for two periods, in which only *one* investment and *one* saving decision are made. In the second period, investment is always zero and all income and wealth is consumed. This framework therefore precludes any interesting saving investment dynamics. It takes a long- or infinitely-lived economy to make a meaningful distinction between the short run and the long run. For this reason, Vikøren's theoretical results for the short–run and long–run correlation are based on fallacious arguments, although the intuition behind them originates in general equilibrium models.[10]

3.3 What Does the SI Correlation Say about Capital Mobility?

Before turning to the empirical part of this paper, we address the crucial question whether the SI correlation contains information about capital mobility and if so, in what sense. Feldstein and Horioka (1980) stated that full capital mobility implied a zero correlation whereas high positive correlations pointed to limited capital mobility. We argue that Feldstein and Horioka's basic idea that the SI correlation contains information about international capital mobility is correct, but that the interpretation of the estimated correlation value must be altered substantially in view of the results derived from modern macroeconomic models.

Severely limited international capital mobility inevitably pins down the SI correlation at a high positive value, regardless of the size and nature of the shocks the economy is exposed to. Note that this is a sufficient, but not a necessary condition for high positive correlations. As has been pointed out repeatedly in the literature, high positive correlations can also be generated in the presence of full capital mobility. Consequently, we cannot ascertain which phenomenon a high correlation signifies without additional information: low capital mobility or a correlation due to shocks, imperfectly integrated good markets, or the like under significant capital mobility. Relevant prior information comprises *inter alia* return differentials, direct measures of foreign exchange regulations, and structural breaks.

[10]Moreover, he does not allow for structural breaks. This leads to incorrect inferences concerning the dynamic behavior of S and I as we will show in section 5.

On the other hand, small positive, zero, and negative correlations can only be generated if capital is sufficiently mobile. This implies that whenever we establish values of the SI correlation to be in this range, we can unambiguously conclude that there is significant capital mobility.

The arguments above make clear that the correlation alone cannot be used to make inferences about the *degree* of capital mobility. For example, a correlation of 0.3 does not necessarily represent a lesser degree of capital mobility than a value of 0.1, since these values can (but need not) be produced under the same degree of (significant) capital mobility, reflecting different impacts of other factors. By the same token, it is not possible to associate a particular value of the correlation like Feldstein and Horioka's zero, or a range of values, with perfect capital mobility. Feldstein (1983: 130) claimed that, strictly interpreted, the Feldstein-Horioka test was on "the extreme hypothesis of perfect capital mobility", whereas we argue that such a test is not possible: At best we can reach the qualitative result that significant capital mobility prevails. Without additional information, the SI correlation can only be used to reject the hypothesis of capital immobility.[11]

When the SI correlation is high, meaningful conjectures about capital mobility can be derived only by consulting further sources of information. For instance, zero return differentials and the absence of institutional rigidities point to substantial capital mobility. Strict capital controls lead to the reasonable suspicion of restricted capital mobility; still we do not know *to what extent* the low capital mobility is responsible for the high correlation. However, if a reliable time profile of factors influencing the correlation, in this case capital controls, is available and the SI correlation reacts systematically and consistently to the varying restrictiveness of the regulations, we can conclude that the difference in the correlation value is caused by a different degree of interference in the free flow of capital. Only in this case a *difference* in the estimated SI value can be said to reflect a *difference* in capital mobility.

[11] We cannot reject the hypothesis of capital mobility and we must not regard high correlations in itself "as evidence that there are substantial imperfections in the international capital market" (Feldstein 1983: 131), because high correlations can have very different, complex causes, only one of which is low capital mobility.

4 Capital Controls and Oil Discoveries – Important Norwegian Peculiarities

Norway offers several advantages for an empirical study. First, since it is a small country, the feedback effects of variations in domestic saving or investment via altered world market conditions can be neglected. Second, the system of Norwegian capital controls, which varied in the degree of tightness, allows us to *directly* measure the effect of government behavior on capital mobility. Since the SI correlation constitutes only an indirect measure of capital mobility we can discern whether these two measures generate matching results.

By 1954, the beginning of our sample period, Norway had eliminated virtually all restrictions on current account transactions, while capital account transactions remained strictly regulated. Transborder portfolio investment was *de facto* prohibited, borrowing abroad required restrictively granted licenses,[12] and inward direct investment was made subject to concessions tied to certain conditions. The minor amount of outward direct investment was treated liberally. Narrow ceilings for banks' net foreign position were stipulated and nonresidents were restricted from holding Kroner accounts, just as residents were restricted from holding foreign exchange accounts. The shipping sector (including shipbuilding) and, later, the oil sector were exempted from exchange regulations and denied access to the domestic credit market due to their large and fluctuating finance requirements.

The first noteworthy liberalization took place in June 1973, when the prohibition to buy Norwegian stocks was eased somewhat. The Fall of 1978 marks the second important step: banks had to balance only their combined (spot *and* forward) foreign exchange position instead of strict limits separately on both positions. It followed a period of gradual and cautious liberalization, especially with regard to inward portfolio investment (Fall '79, Spring '82), but also outward portfolio investment and bank regulations were eased. A major liberalization package entered into effect in June 1984, affecting almost all sorts of transactions. Controls were tightened somewhat in 1985/6, but gradually dismantled thereafter. They were phased out by July 1, 1990. Regulations on the domestic credit market were dismantled with a time lead compared to foreign exchange regulations. The official stipulation of almost all interest rates was discontinued in December 1977, but reintroduced for two years in September 78, when a general wage and price freeze included all lending

[12]The ceiling for borrowing abroad was set in the national budget according to what was deemed "necessary" for the Norwegian economy and could therefore vary from year to year.

rates.[13]

Third, the emergence of the oil sector has a substantial impact on our analysis since it marks an important structural break. The first oil field (Ekofisk) was discovered in December 1969; because of high production costs, however, oil field development became profitable on a large scale only after the first oil price shock of 1973/74 when prices quadrupeled. The build-up of oil and gas production facilities was financed to a large extent by foreign capital resulting in record net capital imports. The oil bonanza spilt over to the mainland economy and caused the whole economy to boom. The rising importance of the oil sector is demon-

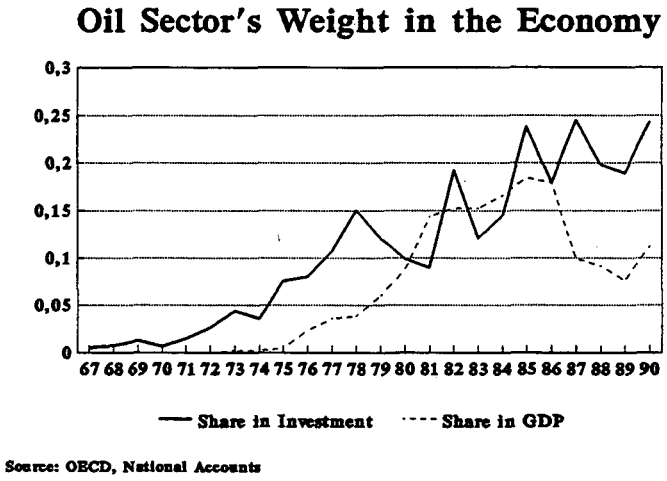

Figure 1: The emerging oil sector

strated by figure 1, which plots the oil sector's share of gross investment and its share in GDP. All data were taken from OECD, National Accounts, as described in appendix A.

Lastly, the shipping and shipbuilding sector was extremely outward oriented. Shipping contributed around 10 % to GDP until the 1968, when its share started to decline considerably. During 1983 to 86 a dramatic flagging out took place for tax reasons until the International Shipping Register was established in 1987, which reversed the trend.[14]

[13]For a more detailed description and further references see Jansen and Schulze (1993) and the literature cited there. Note that it is impossible to describe accurately the actual restrictivenes of the regulations, because it depends on the use of the authorities' discretionary scope (on which no systematic information is available). This use may vary within a constant legal framework. Typically, the lifting of a restriction was preceded by a more liberal handling of this restriction.

[14]For further reference see Hodne (1983), Galenson (1986), and Jansen and Schulze (1993).

5 Empirical Results

We estimate our error correction model (1) on annual data for Norway over the period 1954-89. Domestic investment is defined as the private sector's and government sector's net investment including the change in stocks; saving is the sum of private and government net saving. Both saving and investment are converted into rates by dividing them by net disposable income.[15] Our main data source is the OECD National Accounts; for details see appendix A. Estimation of eq. (1) is done by OLS, after testing for the exogeneity of ΔSR by means of a Hausman (1978) test; see appendix B. The test indicates that ΔSR can be treated as an exogenous variable, so we refrain from using Instrumental Variables methods.

The estimation results, shown in the first column of table 1, reproduce the results in Vikøren (1991), despite minor differences in sample period, specification and estimation method. The estimate for the short–run coefficient is not significantly different from zero at any reasonable significance level. Furthermore, the hypothesis that $\alpha = \delta = 0$, or saving equal investment in the long run, could not be rejected (F(2,33) statistic yields 0.54). All diagnostic tests are passed.

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[15]Since the empirical part of our paper builds on Vikøren (1991), we employ the same definitions he did. However, using gross investment and gross saving expressed as shares of GDP hardly affects the results.

We examined the time series properties of IR and SR by carrying out the Augmented Dickey–Fuller (ADF) test. Addition of the one–period lagged first difference of the variable in question sufficed to make the residuals of the ADF regression appear white noise. The ADF (1) statistic for IR was -3.07 (almost significant at the 10 % level) and for SR it was -4.30 (significant at the 1% level). Critical values for our sample size were calculated on the basis of MacKinnon (1991). In view of the low power of the ADF test in small samples, we conclude that the saving rate and the investment rate can be considered stationary in levels.

Although the use of shares is standard practice in empirical work, Ronning (1992) points out that this may render OLS inefficient. The transformation into shares confines the values of the time series to a specific interval and this may give rise to non-normal and heteroskedastic disturbances. However, our diagnostic tests always point to normality and homoskedasticity of the residuals and hence the use of OLS is warranted.

Table 1: SI relations, eqs. (1) and (6)

	eq. (1)		eq. (6)
constant	0.001		0.010
	(0.02)		(0.33)
ΔSR_t	-0.025		
	(0.13)		
$D_{(54-73)}\Delta SR_t$			0.655
			(2.02)
$D_{(74-78)}\Delta SR_t$			-1.257
			(2.75)
$D_{(79-89)}\Delta SR_t$			0.012
			(0.06)
$SR_{t-1} - IR_{t-1}$	0.281		0.401
	(2.19)		(3.30)
SR_{t-1}	0.029		-0.030
	(0.14)		(0.17)

	eq. (1)		eq. (6)
σ	0.027		0.024
$\bar{R}^2$	0.174		0.372
DW	1.947		1.963
BG(1)	0.051		0.058
BG(2)	1.637		1.888
ARCH(1)	0.041		0.517
JB	0.555		1.327
H (ΔSR_t)	0.721		1.735

Sample period: 1954-89. Explanation of diagnostic statistics and data sources: see appendix. t-statistics in parentheses.

The zero estimate of the short–run coefficient indicates significant capital mobility. This is a striking result as it amounts to an "inverted" Feldstein–Horioka puzzle: We estimate a zero coefficient, while expecting a highly positive one due to severe capital controls that were in place during the greater part of the sample period. Our finding that saving equal investment in the long run accords with our theoretical framework, thereby providing supportive evidence for our approach.

Next, we look into possible structural breaks. To facilitate their detection, figure 2 plots the time series for the saving and investment rate. Especially during the sixties they moved together, but the behavior of both variables changed dramatically in the early seventies, when investment jumped to an all time high and saving plummeted to an all time low. The opposite movements can be attributed to the combined effect of discoveries of large oil and gas deposits and the sharp rise in the oil price in 1973, which made the exploitation of the oil fields on a large scale profitable.[16] Intertemporal consumption smoothing in response to an unanticipated wealth increase can explain the observed saving pattern. Consumption went up because permanent income (in contrast to current income) had increased, driving the

[16]Dooley et al. (1987, footnote 7) mention the possibility of a negative SI correlation in case of oil discoveries. However, they do not explain this phenomenon.

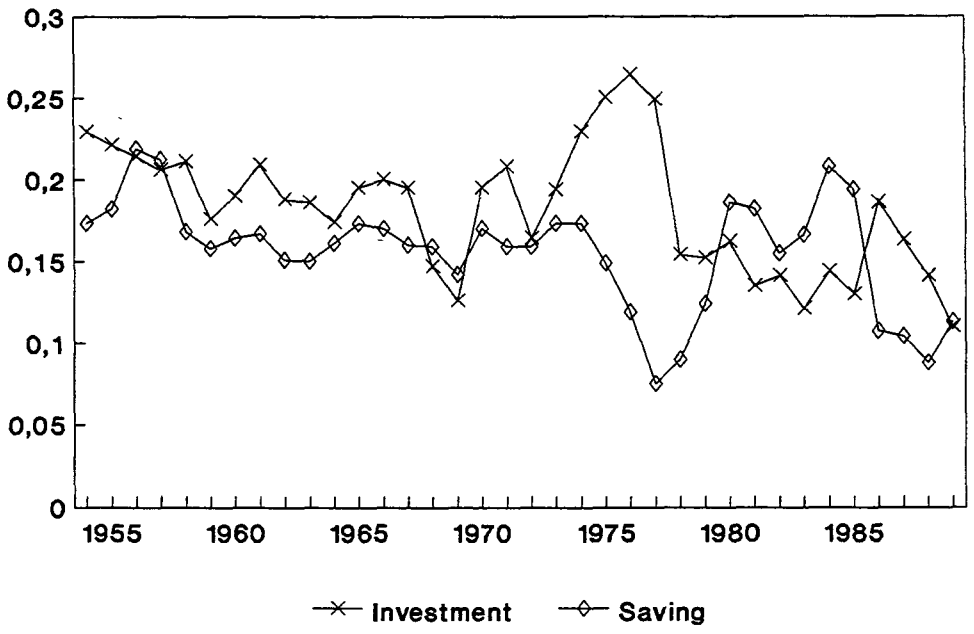

Figure 2: Saving and Investment in Norway, 1954-1989

saving rate temporarily down. In the course of time, the expected income rise materialized and the saving *rate* returned to normal. The temporarily increased investment rate can be explained by the huge investments needed to build up the oil sector and by the attendant spill-over effects of the oil investments on the mainland sector. Together with the increased consumption demand, this added up to a buoyant investment climate.

Judging by the graph, investment and saving were positively correlated until the oil boom and negatively correlated for the period 1974-78, while thereafter there is no clear correlation. So it could well be that the zero correlation we have found masks structural shifts in the parameters. We have investigated this possibility by reestimating eq. (1) allowing the parameters to vary. We specified three regimes: 1954-73, 1974-78 and 1979-89.[17] The second column of table 1 reports the estimates of the ECM with time–variable short–run coefficients,

$$\Delta IR_t = \alpha + (\beta_1 D_1 + \beta_2 D_2 + \beta_3 D_3)\,\Delta SR_t + \gamma(SR_{t-1} - IR_{t-1}) + \delta SR_{t-1} + \epsilon_t \qquad (6)$$

where D_i $(i = 1,2,3)$ denote dummies that are one during subperiod i, and zero

[17]We also investigated other subdivisions of the sample period. The division for which results are reported generates the highest likelihood. Note that the second subperiod coincides with the first investment boom in the oil sector (cf. section 4), thereby also providing intuition for this split-up.

otherwise.[18] The hypothesis that the short–run coefficient is constant is rejected at the 1 % level (F(2,30) is 6.05) and, again, we cannot reject that saving equal investment in the long run (F(2,30) is 0.62). The fit is much better now and the diagnostic statistics do not indicate any trouble. We checked the stability of eq. (6) by testing for structural breaks in the first and third subperiod. We specifically looked whether the short-run coefficient changed after 1984, when a major liberalization package concerning foreign exchange regulations took effect, or after 1986, when the oil price collapsed. In all cases we are unable to reject our empirical model at the 5 % significance level.[19]

The estimates show that the short-run correlation is 0.7 from the fifties to the early seventies, when indeed rather strict capital controls were in place. It is negative during Norway's structural adjustment to the oil discoveries, and zero after 1978. Accordingly, the Feldstein–Horioka criterion as set out in section 3.3 diagnoses significant capital mobility for the period after 1973. There exists corroborating evidence for this result. As argued in Jansen and Schulze (1993), the Norwegian money market was basically well–integrated in the world market during the 1980s. They also failed to find any statistically significant influences of the – declining – controls on stock and bond return differentials in the 1980s, although this may be due to the low power of the tests. Moreover, the exchange controls were gradually being dismantled, while the shipping and the growing oil sector had free access to the world capital market to finance their huge and fluctuating investments.

Our finding of significant capital mobility does not imply that the restrictions on cross–border portfolio investment were necessarily ineffective, because the SI correlation relates to net total capital flows and not to net flows of a particular asset. We have merely established the existence of enough open channels between Norway and the world capital market to allow Norway to smooth its aggregate expenditure. Since the time pattern of the short–run correlation is consistent with other information on capital mobility, like asset return

[18]We report a constrained version because the 12 parameter specification is overfitted for the second subperiod (4 parameters for 5 observations). The 6 parameter restrictions that eq. (6) implies cannot be rejected at the 5 % level as F(6,24) is 2.14. The hypothesis of no structural break is rejected at the 1 % level: F(8,24) is 3.46.

[19]We reject a different regime in 1954–63 and 1964–73: F(4,20) = 0.95. Likewise, we reject different β_3s between 1979-1984 and 1985–89 or 1979-86 and 1986–89: the F(1,29) statistics are 1.90 and 3.43, respectively. To assess the effect of the gradual dismantling of capital controls on β_3, we applied the Wilton–Reid technique, which specifies the parameter as an n–degree polynomial of time. We chose n=3 to allow for an inflection point. Testing for the joint significance of the three additional parameters yields an F(3,27) statistic of only 0.95. See Wilton (1975) and Reid (1977) for a description of this method and Dooley and Isard (1980) for an application to the analysis of the effects of capital controls on interest rate differentials.

differentials and the historical evolution of the regulations, we conclude that the "Feldstein–Horioka puzzle" does not exist for Norway.

We conclude this empirical section with an assessment of the empirical relevance of our criticism of other specifications, which is based on theoretical notions. Since our error correction model (1) encompasses the static equation (3), the equation in differences (4), and the partial adjustment equation (5), we are able to test these alternatives against our model. Each of the alternatives implies two restrictions on the ECM specification (see footnote 9). In case of period–dependent parameters, the ECM counts 12 parameters and the number of restrictions is 6 in each case. Table 2 presents the F-statistics.

Table 2: Test of alternative specifications against the ECM

	constant parameters	period-dependent parameters
static, eq. (3)	19.17	2.86
difference, eq. (4)	5.07	5.47
partial adjustment, eq. (5)	0.03	2.94
critical $F_{0.05}$	3.30	2.51
number of restrictions	2	6
degrees of freedom	32	24

The three incomplete regression equations are all rejected in favor of the ECM when we allow for structural breaks. The results for eq. (4) reveal that neglecting the long–run equilibrium is particularly harmful. This outcome provides additional evidence that an ECM is the most suitable equation for measuring the saving investment correlation.

6 The *SI* Correlation and the Oil Sector

Since the emergence of the oil sector marks a structural break, an investigation into its influence on the *SI* correlation is warranted. There is a possibility that the non-oil economy is still rather insulated and that the low estimate of the *SI* correlation is chiefly caused by a large influx of foreign capital into the oil sector, which was dependent on the international capital market for financing of its investments.

It would therefore be illuminating to estimate an SI relation for the rest of the economy alone. However, this encounters problems, because data on saving are not available on industry level; only the total for all industries is available. Data on net investment by industry are available.

We approach the data problem by estimating a two–sector system (oil and non–oil sector) along with a distribution of the net saving between the sectors. The sectoral SI relations are modelled as an ECM. Before 1974 only the non-oil sector existed. Hence, we have

$$\Delta IR_t^n = \alpha^n \Delta DFR_t^n + \beta^n IR_{t-1}^n + \gamma^n DFR_{t-1}^n + \epsilon_t^n \qquad 1954-73 \qquad (7)$$

$$\left.\begin{aligned} \Delta IR_t^n &= \alpha^n \Delta DFR_t^n + \beta^n IR_{t-1}^n + \gamma^n DFR_{t-1}^n + \epsilon_t^n \\ \Delta IR_t^o &= \alpha^o \Delta DFR_t^o + \beta^o IR_{t-1}^o + \gamma^o DFR_{t-1}^o + \epsilon_t^o \end{aligned}\right\} \qquad 1974-89 \qquad (8)$$

where the superscripts o and n denote oil and non-oil sector variables and DFR^i $(i = o, n)$ denotes the pool of domestic funds available for financing the sector i's investment, expressed as a fraction of net disposable income. The disturbance vector $(\epsilon_t^n \ \epsilon_t^o)'$ has a normal distribution with a zero mean and covariance Ω, while during 1954-73, ϵ_t^n has a normal distribution with a zero mean and variance ω^n, the element of Ω in the upper–left corner.

Since the oil sector was not allowed to borrow domestically, the pool of *domestic* funds available to this sector consists of its own retained profits (internal funding). The remainder of national saving is at the disposal of the non–oil sector. The oil sector is assumed not to invest in the mainland sector and vice versa. We can write the unobservable DFR^n and DFR^o as

$$DFR_t^o = \tau_t^o SR_t^p \qquad (9)$$

$$DFR_t^n = SR_t - DFR_t^o \qquad (10)$$

where τ^o is the oil sector's share in private sector saving, SR^p. We postulate that τ^o is a function of oil price changes and the oil sector's share in the total operating surplus (OS), as this is the variable that comes closest to saving. The difference between operating surplus and saving consists mainly of the remuneration of financial capital (interest and dividend payments) and taxes. We postulate a linear relation between τ^o and its determinants:

$$\tau_t^o = v_0 + v_1(OS_t^o/OS_t) + v_2 \hat{p}_{\text{oil}} \qquad (11)$$

where $\hat{p}_{\text{oil}}$ denotes the oil price's rate of change, quoted in US dollars. Combining eqs. (7) – (11) we obtain our system, which is estimated by Maximum Likelihood. Assuming serial

independence of the disturbances, we can write the log likelihood of the whole sample as (ignoring constants)

$$\mathcal{L} = -\frac{1}{2}\left\{\sum_{t=54}^{73}(\epsilon_t^n)^2/\omega^n + 20\ln\omega^n + \sum_{t=74}^{89}(\epsilon_t^n\ \epsilon_t^o)\,\Omega^{-1}\,(\epsilon_t^n\ \epsilon_t^o)' + 16\ln|\Omega|\right\}. \qquad (12)$$

The log likelihood prior to 1974 (20 years) refers only to the non-oil sector, while after 1973 (16 years), it refers to the two equation system. Table 3 shows the results for the system with time-dependent α^n and α^o, where the sample period is partitioned as in table 1. The estimates for the non-oil sector bear strong resemblance to those in table 1. Testing whether α^n is the same across subperiods (2 restrictions) gives us a Likelihood Ratio statistic of 11.45, so we can reject this hypothesis at the 1% level.

Table 3: ML estimates of the two sector system, eqs. (7) - (8)

	Non-oil sector		Oil sector
$\alpha_{(54-73)}$	0.7104		–
	(2.87)		
$\alpha_{(74-78)}$	-1.0282		-1.0625
	(1.95)		(1.73)
$\alpha_{(79-89)}$	0.0834		0.0211
	(0.31)		(0.14)
β	-0.5698		-0.1003
	(5.27)		(0.74)
γ	0.6462		0.0691
	(5.01)		(0.84)
v_0		-0.0174	
		(0.73)	
v_1		2.2574	
		(6.75)	
v_2		0.1073	
		(1.82)	

	Non-oil sector		Oil sector
sdev	0.0264		0.0130
σ	0.0178		0.0110
DW	2.39		2.32
BG(1)	0.64		0.55
BG(2)	3.33		0.68
JB	1.04		2.63
ARCH(1)	1.00		2.14

Sample period: 1954-89. t-statistics in parentheses, for data sources and explanation of test statistics see appendix.

We have carried out a sensitivity analysis of our results by estimating eqs. (1) and (6) for the non–oil sector, assuming that the oil sector has financed its investment entirely by foreign sources. This leaves national saving as the pool of domestic funds the non–oil sector can draw from for its investment. Since even under these extreme assumptions the results

are comparable to those in table 1, we reach the same conclusion as for the total economy: the non-oil economy operates under conditions of significant capital mobility since 1973. This outcome is broadly consistent with other indicators of capital mobility.[20]

7 Conclusion

The correlation between saving (S) and investment (I) is at the core of modern macroeconomics since it represents important stylized facts theory is to explain. Reliable measurement of the correlation requires an econometric specification with a sound theoretical foundation in order to avoid biased results and to allow meaningful interpretations. Only error correction models (ECM) meet this requirement because up-to-date intertemporal general equilibrium models imply a cointegrating relation between S and I. In the most obvious and most frequently analyzed case, saving equals investment in the steady state and deviations from this equality (current account imbalances) are temporary phenomena. The specifications used up until now are seriously flawed because they ignore the dynamics or the steady state relation between S and I. Drawing on Feldstein and Horioka (1980), we argue that the possibility of deriving inferences about capital mobility from the SI correlation is asymmetric. While low or negative correlations presuppose significant capital mobility, high correlations can be produced under both low and high capital mobility. Without additional information it is impossible to identify which state prevails in the latter case.

Applying the ECM to Norwegian annual data for 1954 - 89 underpins our methodological arguments. The long-run relation between S and I is consistent with the steady state equality and the ECM also outperforms previous specifications empirically. Moreover, we demonstrate the need for careful testing for structural breaks. While regressing over the whole sample period would have created an "inverted Feldstein–Horioka puzzle" (zero short-run correlation despite strict capital controls during the larger part of the sample), we detect that the oil boom breaks the sample period into three regimes, for which the short-run correlation accords with the history of Norwegian capital controls. The correlation is positive and high in the times of tight controls prior to the oil boom, negative during the oil boom 1974-78, when Norway adjusted to the unanticipated increase in wealth and investment demand, and zero thereafter, when controls were gradually dismanteled. This time pattern holds even if we exclude the oil and shipping sectors, which in contrast to the

[20] We have repeated all estimations for the economy excluding the oil *and* the shipping sector and obtain similar results. They are reported in appendix C.

rest of the economy were not affected by capital controls. The "Feldstein–Horioka puzzle" does not hold for Norway: Capital has been shown to be mobile from 1974 onwards and we find a remarkable coincidence of the tightness of capital controls and the value of the SI correlation.

As for future research, a panel design seems to be the most suitable econometric framework to estimate the SI correlation since it allows for the incorporation of both dynamics and cross-country parameter restrictions. An additional advantage of the panel design lies in the more efficient estimation, thanks to the exploitation of the contemporaneous correlation of the disturbances reflecting common shocks. Stylized facts, like structural breaks and similarities in saving investment dynamics across (subsets of) countries, can easily be established by testing parameter restrictions. Note that the panel design is a generalization of the design used by Feldstein and Horioka (1980), who impose the restriction that the saving investment correlation is equal both across countries and over time.

In the end we may find that the result found for Norway carries over to other countries so that the "Feldstein–Horioka puzzle" would cease to exist, or be confined to a group of countries. This outcome is not necessary, but even if Norway turns out to be an exception and the puzzle is confirmed in general, it will have been given a much firmer statistical foundation than it currently enjoys.

A Data sources

The main source of the data is the *OECD National Accounts, Volume II*, published annually by the OECD. Table 1 (*Main aggregates*) contains all the data needed to compute the investment and saving rate as defined in the main text.

Gross investment for the oil sector is taken from table 3, line 7, (*Gross fixed capital formation by kind of activity*) and depreciation and operating surplus are taken from table 13, line 7, (*Cost components of value added by kind of activity*). Comparable data for the shipping sector were made available by the Central Bureau of Statistics in Oslo. Total operating surplus is taken from table 1. The price of oil is taken from *International Financial Statistics*, published by the International Monetary Fund, table *Commodity prices*, line 456.

Concerning the instruments used in the Hausman exogeneity test, defense spending is taken from *OECD National Accounts*, table 5 (*Total government outlays by function and type*), direct taxes from table 6 (*Accounts for general government*) and wage income from table 1. The dependency ratio is defined as the ratio between the number of people aged less than 15 or more than 65 years old and the number of people aged 15 to 65 years old. Data are taken from the *Labour Force Statistics*, published by the OECD, table 1. All instruments (except the demographic variable) are expressed as shares of net disposable income.

B Explanation of the Test Statistics in the Tables

σ is the standard error of the regression, $\bar{R}^2$ the coefficient of multiple correlation adjusted for degrees of freedom, DW the Durbin-Watson statistic and sdev the standard deviation of the dependent variable. BG(1) and BG(2) are Breusch-Godfrey statistics, testing for first and second autocorrelation in the residuals, respectively. Their distribution under the null hypothesis of zero autocorrelation is $\chi^2(1)$ and $\chi^2(2)$, respectively. ARCH(1) tests for first order autoregressive conditional heteroscedaticity, see Engle (1982). Its distribution under the null hypothesis of homoscedasticity is $\chi^2(1)$. JB is the Jarque-Bera statistic testing for nonnormality of the residuals. Its distribution is $\chi^2(2)$ under the null hypothesis of normality.

H(ΔSR_t) denotes the Hausman-test, which is conducted by regressing ΔSR_t on a set of instruments and using the residuals of that projection as an additional regressor in the original regression. In case of exogeneity the projection residuals have no additional explanatory power. The test statistic is the t-value of the added variable's parameter estimate. As instruments we used one and two period lagged values of saving and investment, one period lagged wage income and direct taxes, current defense spending, and the dependency ratio. The latter two instruments were also employed by Dooley et al. (1987) and Frankel (1991).

C Sensitivity Analysis for the Results on the Oil Sector

In section 6 we showed that since 1973 the non-oil sector (like the oil sector) has operated under conditions of significant capital mobility. This section demonstrates that this result is insensitive to assumptions on the distribution of national saving between the two sectors. Moreover, the result stands up if we exclude not only the oil sector but also the shipping sector.

We have estimated slightly rewritten versions of eqs. (1) and (6)[21] under the extreme assumption that all investment of the excluded sectors is financed by borrowing abroad. In other words, the pool of savings for non-oil investment in the first case and mainland investment (total economy minus oil and shipping sectors) in the second case is then simply national saving.

Table 4 reports the estimated SI relations for the non-oil sector and the mainland sector. The results are comparable to the estimates for the whole economy reported in table 1, although the fits are somewhat poorer. As for the β s, the estimated short–run correlation during the oil boom is again less than zero, but it is smaller in absolute value and no longer significantly negative. This can be explained by the fact that the lion's share of the increase in investment in 1974–78 was absorbed by the build-up of the oil sector. All diagnostic tests are passed. Judged from these estimates the short-run SI correlation was about 0.7 prior to 1974 and approximately zero thereafter.

Table 4: SI relations, for the non-oil and mainland sector, eq. (1) and (6)

	Non-oil sector		Mainland sector	
ΔSR	0.0215		0.0417	
	(0.13)		(0.27)	
$D_{(54-73)}\Delta SR$		0.6307		0.7040
		(1.97)		(2.35)
$D_{(74-78)}\Delta SR$		-0.4300		-0.3537
		(0.98)		(0.85)
$D_{(79-89)}\Delta SR$		-0.0898		-0.0964
		(0.45)		(0.53)
IR_{t-1}	-0.2414	-0.2654	-0.2229	-0.2583
	(2.86)	(3.00)	(2.53)	(2.79)
SR_{t-1}	0.2465	0.2658	0.2100	0.2388
	(2.63)	(2.79)	(2.36)	(2.64)

	Non-oil sector		Mainland sector	
σ	0.0252	0.0241	0.0238	0.0223
$\bar{R}^2$	0.142	0.215	0.103	0.211
DW	1.96	2.02	1.78	1.93
BG(1)	0.00	0.04	0.11	0.01
BG(2)	1.61	1.52	1.64	0.19
JB	0.22	1.15	0.46	0.47
ARCH(1)	0.34	1.27	0.24	0.03
H(ΔSR)	1.00	1.45	0.77	1.29

Sample period: 1954-89. t-statistics in parentheses. Cf. appendices A and B for test statistics and data sources.

[21] We report only one coefficient for SR_{t-1}, which equals $\gamma + \delta$ of eqs. (1) and (6). The coefficient for IR_{t-1} is $-\gamma$ of (1) and (6). We ignore a constant term which was found to be not significantly different from zero.

For the sake of completeness we report the maximum likelihood estimates of the two sector system as described in section 6, now however the economy being split into the oil and shipping sectors on the one hand and the mainland economy (non-oil non-shipping activities) on the other.

Table 5: ML estimates of the two sector system, mainland economy and oil + shipping sector, eqs. (7) - (8)

	Mainland		Oil + Shipping
$\alpha_{(54-73)}$	1.974		-0.1361
	(2.12)		(0.39)
$\alpha_{(74-78)}$	-0.7700		-0.3606
	(2.02)		(0.71)
$\alpha_{(79-89)}$	0.0033		0.1667
	(0.01)		(0.59)
β	-0.4319		-0.3240
	(3.87)		(3.15)
γ	0.4681		0.2933
	(3.36)		(1.87)
v_0		-0.0119	
		(0.52)	
v_1		1.6547	
		(3.32)	
v_2		0.2293	
		(1.60)	

	Mainland	Oil + Shipping
sdev	0.0243	0.0202
σ	0.0185	0.0178
DW	1.937	2.318
BG(1)	0.013	1.243
BG(2)	1.323	1.257
JB	0.52	0.543
ARCH(1)	0.199	0.928

Sample period: 1954-89. t-statistics in parentheses, for data sources and explanation of test statistics see appendices A and B.

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