BOFIT
Discussion Papers

2000 • No. 4

**Vadims Sarajevs**

# Econometric Analysis of CurrencySubstitution: A Case of Latvia

Bank of Finland
Institute for Economies in Transition
BOFIT

# Bank of Finland Institute for Economies in Transition BOFIT

## Economists

**Mr Pekka Sutela, head**
Russian economy and economic policy
Russia's international economic relations
Baltic economies

**Mr Tuomas Komulainen, economist**
Russian financial system
Currency crises

**Mr Iikka Korhonen, economist**
Baltic economies
Russian financial system

**Ms Seija Lainela, economist**
Baltic economies
EU policy and Eastern relations
Russian economy and economic policy

**Mr Juhani Laurila, senior adviser**
Russian economy and economic policy
Baltic countries' external relations

**Mr Tom Nordman, senior adviser**
Chinese economy
Foreign exchange markets

**Mr Jukka Pirttilä, research supervisor**
Public economics
Transition economics

**Mr Jouko Rautava, economist**
Russian economy and economic policy

**Mr Jian-Guang Shen, economist**
Chinese and East Asian economies
Currency crises

**Ms Laura Solanko, economist**
Fiscal federalism
Russian regional issues

## Information Services

**Ms Joanna Ahlberg, department secretary**
Department coordinator, publications traffic

**Mr Timo Harell, senior clerk**
Press monitoring

**Ms Päivi Määttä, information specialist**
Institute's library, information services

**Ms Tiina Saajasto, research secretary**
Statistical analysis, statistical data bases

**Ms Liisa Sipola, research secretary**
Information retrieval, Institute's library and publications

## Publications

**Russian and Baltic Economies – The Week in Review**
A two-page weekly review of the previous week's focal events in Russia and the Baltic states.

**Russian Economy – The Month in Review**
A four-page review with analysis of developments in Russia's economy, fiscal policy and financial markets.

**Baltic Economies – The Quarter in Review**
A four-page review with analysis of recent economic developments in Estonia, Latvia and Lithuania.

**BOFIT Discussion Papers**
A series devoted to transition issues. Contains academic studies on transition economics by BOFIT economists and guest researchers.

**BOFIT Online**
An electronic publishing series devoted to transition issues. The focus is on descriptive work on economic policy and economic developments in transition economies. Papers are either in English or Finnish.

---

## Contact us

Bank of Finland Institute for Economies in Transition (BOFIT)
P.O. Box 160 FIN- 00101 Helsinki
Phone: +358 9 183 2268 Fax: +358 9 183 2294 Email: bofit@bof.fi (firstname.surname@bof.fi)
Web: www.bof.fi/bofit

BOFIT
Discussion Papers

2000 • No. 4

**Vadims Sarajevs**

# Econometric Analysis of Currency Substitution: A Case of Latvia

Bank of Finland
Institute for Economies in Transition
BOFIT

ISBN 951-686-922-X (print)
ISSN 1456-4564 (print)

ISBN 951-686-923-8 (online)
ISSN 1456-5889 (online)

Suomen Pankin monistuskeskus
Helsinki 2000

# Contents

# List of Tables



# List of Figures

Vadims Sarajevs*

# Econometric Analysis of Currency Substitution: A Case of Latvia

## Abstract

The paper provides a comprehensive econometric analysis of currency substitution for Latvia. Rather than drawing inferences on the degree of currency substitution from domestic money demand modelling, the most common approach to empirical analysis of the phenomenon, direct modelling of currency substitution ratio is applied. Extensive model construction, estimation, evaluation and testing are performed. Methodological issues are also discussed. No simple policy recommendations can be made at this stage of research, but a number of instruments are identified, which can be used by the authorities to influence currency substitution behaviour.

**Key words:** Currency substitution, exogeneity, unit roots, causality, cointegration, parameter constancy

**JEL classification:** C22, C51, C52

* The author is grateful to Professor Mikael Linden from the University of Helsinki for helpful advice, comments and discussions, as well as to several participants in a seminar on the subject held by the Bank of Finland's Institute for Economies in Transition: Jukka Pirttilä, Tuomas Komulainen and Iikka Korhonen. Any errors are solely the responsibility of the author.

# 1 Introduction

During transition many governments rely heavily on monetary policy to achieve macroeconomic stabilisation. Arguably, extensive currency substitution and dollarisation of the national economy can seriously hinder the effectiveness of monetary policy. Even today, currency substitution and dollarisation are rampant in countries of the former Soviet Union, and extensive in many other East European transition economies. Here, we focus on the issue of econometric analysis of the phenomenon of currency substitution. A complementary aim of the study is to expose explicitly the methodologies used in research and provide as many details of the path from initial model to final result allowed within the constraints of this short paper.

Calvo, G. A. and C. A. Vegh (1992) have well documented the phenomenon of currency substitution in developing countries. Savastano, M. A. (1992 and 1996) had provided similar insightful studies on Latin America. Recent surveys of theoretical and empirical problems and developments in the field include the excellent paper by Giovannini, A. and B. Turtelboom (1994) and the wide-ranging book by Mizen, P. and E. J. Pentecost (1996). However, a cursory search of transition economy literature also immediately reveals an appalling deficit of research. As of 1999, a single survey (Sahay, R. and C. A. Vegh (1995)) documented the problem of currency substitution in transition economies. Barring the notable contribution of Mongardini, J. and J. Mueller (1999), who model the currency substitution ratio explicitly using monthly data for the Kyrgyz republic, no significant empirical research exists. Of course, earlier empirical research such as that of Charemza, W. W. and S. Ghatak (1990), Lahiri, A. K. (1991), and Frenkel, J. A. and M. P. Taylor (1993) addresses the problem of money demand and inflation in the presence of foreign currency. But again, these papers deal primarily with the pre-transition situation of planned economies. A possible conclusion to be drawn from this dearth of literature is that currency substitution constitutes a problem of extreme complexity. Indeed, the interactions of numerous economic factors with institutional arrangements and the transmission mechanisms are poorly understood.

Furthermore, all published empirical research on currency substitution in transition economies, with the exception of Mongardini, J. and J. Mueller (1999), employ two arguably unfavourable features. First, they are based on quarterly data sets, so sample sizes are small, usually only twenty to thirty observations. This seriously impairs the value of any inferences drawn from econometric analysis. Many tests, especially unit root tests, simply lack the power to discriminate between competing alternatives such as stationary versus non-stationary or cointegrated versus not-cointegrated time series. By contrast, the data sample we use in our analysis for Latvia is constructed from monthly time series, so it comprises over seventy observations – more than double of an average sample size used in earlier research. The problem of low power tests is significantly reduced due to a large increase in the degrees of freedom. Second, earlier tests do not model the behaviour of currency substitution ratio per se. Instead, they deal with indirect evidence of currency substitution such as the influence of foreign exchange variables (the expected rate of exchange rate depreciation) and variables of foreign origin (foreign interest rates and inflation) on domestic money demand.[1] While this approach obviously has its proponents, we would argue it is a rather obscure way to answer questions on the actual nature and behaviour of currency substitution. We do not dispute the factual findings of such empirical research. Interest differentials (spreads between domestic and foreign rates of return), inflation and the expected rate of exchange rate depreciation all are important determinants of money demand in presence of currency substitution phenomenon. Our purpose is merely to utilise these explanatory variables together with others in our research.

In the course of our research we found that the volatilities of government expenditures and inflation as a proxy for the general level of uncertainty in the economy may be important determinants of the level of currency substitution (Sarajevs, V. (1999)). We also empirically investigated

1 The bulk of research in the 1980s and first half of the 1990s primarily dealt with the stability of domestic monetary aggregates in the presence of currency substitution (taken as given), and the effects of currency substitution on the behaviour of domestic inflation, exchange rate and seigniorage revenues. The phenomenon of currency substitution was not studied in isolation, but rather as a condition complicating the issues of earlier studies. This situation is all the stranger, given that the first theoretical model dealing with currency substitution ratio (share of foreign assets in total wealth) directly was proposed by Thomas, L. R. (1985, especially, p. 350) in 1985. His approach, with certain modifications, was taken up by Calvo, G. A. and C. A. Vegh (1992, pp.: 22-4), and Sahay, R. and C. A. Vegh (1995, pp.: 3-6). In empirical research for developing countries a recent paper by Agenor, P. R. and M. S. Khan (1996, pp.: 107-9) models currency substitution ratio per se.

the issue of uncertainty in the phenomenon of currency substitution. Apart from the paper by Boero, G. and G. Tullio (1996), who found a small positive effect of the exchange rate volatility on domestic real money demand in Germany, this issue has been completely neglected.

Clearly, an empirical research on currency substitution in transition economies is long overdue. Beyond the lack of research and poor theoretical understanding of this phenomenon generally, we would argue that the process of transition in Latvia specifically bears many common features and similarities to the transformation of many economies in Central and Eastern Europe. Therefore, the resulting framework of a case study can be easily applied and expanded to the study of other country-specific cases or to panel data analysis.

The plan of this paper is as follows. We start with the section

2 Theoretical and Empirical Background: A Brief Overview to introduce the subject of currency substitution and related problems. Then in the section

3 Data and Methodology, we describe our data sample, sources and problems characteristic for data on transition economies. Relevant methodological issues are discussed. In the section

4 Univariate modelling, we apply a univariate modelling approach to currency substitution time series. No explanatory variables are present. The resulting model can be thought as a benchmark model against which the performance of any other more complicated model can be judged. In the section

5 Multivariate modelling candidates for explanatory variables are discussed and selected, and an appropriate model is presented and discussed. The section

6 Conclusion does just that.

## 2 Theoretical and Empirical Background: A Brief Overview

The problem of currency substitution is fairly new. Its modern development originates in the works of Kouri, P. (1976), and Calvo, G. A. and C. A. Rodriquez (1977), who considered the behaviour of the real exchange rate in the presence of currency substitution. They found that the real exchange rate should depreciate as a result of a rise in the money supply growth rate.

What is currency substitution actually? Nearly every paper in the literature discusses the definition. On one pole – the narrow definition – we find Calvo, G. A. and C. A. Vegh (1992), who define currency substitution as the usage of foreign currency as medium of exchange only. They distinguish it from dollarisation, although the term is widely used as a synonym for currency substitution. For these economists, the term dollarisation applies to a situation where a foreign currency performs the roles of unit of account or store of value, but not necessarily medium of exchange. In this view, currency substitution is the last stage of the dollarisation process that typically starts in high-inflation environments where a foreign currency becomes the unit of account or store of value. At the other pole – the broad definition – we find McKinnon, R. I. (1985), whose concept of indirect currency substitution, i.e. when investors switch between non-monetary financial assets of different countries, cannot be easily distinguished from the concept of capital mobility. Between these extremes, we find an array of definitions. Some see currency substitution as a process where foreign currency substitutes for domestic money in all three roles, i.e. unit of account, store of value and medium of exchange.[2] Others restrict their focus to the store of value function of money. Some researchers simply define currency substitution as a process whereby the demand for domestic money is affected by foreign economic variables that include:

- The relative opportunity cost of holding different currencies (see Bana, I. M. and J. Handa (1990)),
- Foreign inflation (Rogers, J. H. (1990)),
- Real return differential (Thomas, L. R. (1985)),

[2] Agenor, P. R. and M. S. Khan (1996, p. 101).

- Foreign exchange considerations (in particular, the expected depreciation of domestic currency),[3] or
- Nominal interest rates (Madhavi, M. and H. B. Kazemi (1996)).

Giovannini, A. and B. Turtelboom (1994, p. 392) suggest separating the study of currency substitution into two categories. In their view, the study of currency *substitutability* refers to the characteristics of currencies. Thus, one should investigate the potential effects on variables of economic interest, for example, exchange rate value and dynamic, domestic inflation and seigniorage revenue. The study of currency *substitution*, on the other hand, refers to an equilibrium outcome. Here study should investigate the extent and the causes of the replacement of one currency with another.

With transition economies, it seems best to focus on substitution of the domestic currency with the foreign currency serves the store of value function. The following arguments speak for this proposition. First, no transition economy has experienced sufficiently prolonged and or severe periods high inflation and political instability (as in Latin America and many other developing countries) for foreign currency to replace domestic money as the medium of exchange. Second, the lack of bond and stock markets meant there were no other assets available for investments to households at the beginning of transition. Third, once successful stabilisation programs are in place, the dollarisation ratio tends to fall significantly in transition economies (e.g. Poland, Estonia, Lithuania, Mongolia). Sahay, R. and C. A. Vegh (1995, pp.: 11-13) report that timely, determined actions by the government help avoid an unpleasant and costly fight once foreign currency becomes the medium of exchange and a hysteresis effect occurs (see Uribe, M. (1997)).

The questions related to the phenomenon of currency substitution can be summarised into four categories:

1. How does currency substitution affect the dynamic and volatility of the real exchange rate?
2. How does currency substitution affect seigniorage revenue, the behaviour of domestic inflation in the presence of a large budget deficit, and, in general, the stability of monetary aggregates?
3. Should currency substitution be encouraged?

[3] Marquez, J. R. (1987), Calvo G. A. and C. A. Rodriguez (1977), Calvo, G. A. (1985), Rojas-Suarez, L. (1992).

4. How does currency substitution affect the choice of nominal anchors in stabilisation programs?

Only matters relevant for econometric research are discussed below in details. Theoretical models can be classified as well. First, one can divide them into optimising models, where solutions follow from static or dynamic optimisation, and ad hoc models that postulate the functional form of the currency substitution ratio and/or domestic demands. Optimising models, in turn, can be subdivided on cash-in-advance models and transaction cost models. In cash-in-advance models, economic agents are forced to use domestic and foreign currencies as a means of payment due to some form of legal restrictions. Most portfolio-balance models can be assigned to this category. In transaction cost models, money is assumed to provide some kind of liquidity services and to reduce transaction costs. Higher real money balances often mean shorter shopping time, an important decision variable for consumers that value leisure time. Models with money-in-the-utility function also belong in the same category. Feenstra, R. C. (1986) established their functional equivalence with transaction costs models.

Apart from the theoretical confusion, the data itself constitutes a major empirical hurdle to the study of currency substitution. All major surveys on currency substitution discuss this fundamental problem.[4]

Giovannini, A. and B. Turtelboom (1994) suggest that the ideal data set should consist of foreign currency notes circulating in the economy as a means of payment and a store of value, foreign currency checking accounts and short-term deposits held by the residents in the domestic banks and abroad. They further note that even for developed countries (say, OECD states) there is no available data on cross-border credit card and check transactions. The situation with data on developing countries and transition economies is obviously worse. Thus, most studies employ the ratio of foreign currency deposits to M2 as a proxy for the level of currency substitution/dollarisation in the economy. Obviously, this measurement omits foreign currency notes in circulation and, thus, represents only the lower bound for the level of currency substitution. The actual level of currency substitution is higher. The measurement error will be larger the more for-

[4] Calvo, G. A. and C. A. Vegh (1992), Savastano, M. A. (1992), Giovannini, A. and B. Turtelboom (1994), and Sahay, R. and C. A. Vegh (1995), Mizen, P. and E. J. Pentecost (1996).

eign currency stock is in the form of notes. This usually corresponds to periods of high macroeconomic and political instability, or in transition economies, to underdeveloped financial markets and an absence of proper facilities for foreign currency deposits. Even with data on foreign currency deposits there are problems. Often the maturity structure of foreign currency deposits is unknown. Moreover, data on foreign currency deposits held by residents abroad and in offshore banking centres is hard to collect and presumably unreliable.

Nevertheless, there are attempts, while doing research on particular country, to construct a better measure of currency substitution than simply foreign currency deposits. Bufman, G. and L. Leiderman (1992), for example, use so-called Patam accounts in Israel as a measure of currency substitution. Patam accounts are foreign currency deposits in banks that are linked to the exchange rate, so a devaluation brings a one-to-one increase in the account balance in terms of domestic currency.

Savastano, M. A. (1992) also suggests extending the measure of foreign currency deposits to more comprehensive indicators of the extent of currency substitution. He starts by adding to foreign currency deposits all foreign currency notes circulating in the economy outside the banking system. Next he adds all foreign currency assets held abroad by the private sector.[5] The difficulties with getting a reliable estimate of the both quantities were already mentioned above. However, since the U.S. is an obvious safe haven for Latin American residents, one can use data on the deposits in U.S. banks held by foreign nationals from the U.S. Treasury Bulletin as a decent indicator of the overall extent of currency substitution.

Melvin, M. and K. Fenske (1992) attempted to construct a new data set to estimate the degree of dollarisation in Bolivia,[6] using the record of informal loans made in the Cochabamba Upper Valley region. In this active informal loan market, people make loans directly to one another, bypassing intermediaries such as banks. The loans are recorded with local small claims judges. Loans are denominated in both the U.S. dollars and Bolivian currency. The data set contains 5,789 observations dating from January 1980 to June 1987. The dollarisation hypothesis is estimated by a

[5] Rojas-Suarez, L. (1992) used both foreign currency deposits at home and in the U.S.

[6] Melvin, M. and G. Afcha (1989) estimate dollar bills circulating in an economy. Note, however, that such estimates are usually subject to a set of highly restrictive assumptions on the behaviour of domestic money demand and carry a large measurement error.

PROBIT model of the probability of a loan being denominated in dollars as a function of Bolivian inflation, exchange rate depreciation, and exchange rate volatility. Monetary policy reforms of 1985-1987 are modelled with dummy variables. The conclusion from the study of the informal loan market is that the Bolivian stabilisation programme coincided with an increase in dollarisation, rather than a decrease. The authors suggest lack of credibility as a main reason for this outcome.

Thus data limitations imply that only the extent of dollarisation in the limited sense of Calvo, G. A. and C. A. Vegh (1992), i.e. use of foreign currency as a store of value, can be properly studied. It is beyond our purposes to examine the currency substitution phenomenon, i.e. the use of foreign currency as a means of payment and unit of account. Moreover, as emphasised by Calvo, G. A. and C. A. Vegh (1992), dollarisation includes asset substitution, i.e. substitution between interest-bearing assets denominated in domestic and foreign currencies. Therefore, researchers making econometric estimations need to be very cautious with respect to what they test for, currency substitution or asset substitution (capital mobility phenomenon). Cuddington, J. (1983) bases his critique of empirical research on currency substitution on this confusion, which generally exists between currency substitution and asset substitution. He argues that one cannot empirically discriminate between the phenomena of currency substitution and asset substitution in the context of a portfolio model with highly developed capital markets. In such models, the demand for real domestic money balances depends negatively on the expected rate of depreciation (usually considered evidence of currency substitution), no matter if domestic residents actually hold foreign currency.

Sahay, R. and C. A. Vegh (1995) devote considerable attention to problems stemming from the confusion between currency substitution phenomenon (the use of foreign currency as a means of payment and unit of account) and asset substitution (the use of foreign currency as a store of value).[7] Under their thesis, the representative consumer's financial wealth consists of real domestic and foreign money balances, which provide liquidity services by reducing transaction costs, and real holdings of domestic and foreign bonds, which do not provide any liquidity services and are held as a store of value. The consumer optimises his consumption and portfolio. Their model yields the following relationships.

[7] Who based their discussion on the model by Thomas, L. R. (1985).

Let the extent of dollarisation be represented by the sum of real foreign bond and currency holdings. In this case, the degree of dollarisation depends only on the real return differential (plus risk characteristics of the assets and the consumer). On the other hand, the relative money demand (the ratio of foreign to domestic real money holdings is often taken as a measure of currency substitution) depends on the opportunity cost of both currencies, which is represented by domestic and foreign nominal interest rates. Moreover, if the domestic nominal interest rate rises, currency substitution increases (i.e. depends positively on the domestic nominal interest rate), while, all other things being equal, dollarisation should fall (i.e. depends negatively on the domestic nominal interest rate), revealing higher real returns on assets denominated in the domestic currency.

Now assume that a researcher wishes to detect the phenomenon of currency substitution, i.e. he is looking for a positive relationship between the domestic nominal interest rate and the ratio of foreign to domestic real money holdings. The data on the amount of foreign currency bills in circulation in the economy is typically unavailable, so real holdings of foreign bonds (or interest-bearing foreign currency deposits) are used as a proxy for the real foreign currency holdings. Clearly, econometric estimation of such equation will be misleading, because the equation will be wrongly specified. Real holdings of foreign bonds (as established above) are influenced by real returns, not nominal returns.

When domestic nominal interest rates are controlled by the authorities, they very likely do not reflect the opportunity cost of holding the domestic currency. Thus, the expected rate of depreciation (devaluation) can be used as a proxy for the opportunity cost of holding the domestic currency.

Let's now turn to the econometric models and tests typically used to capture and estimate the effects of currency substitution. Giovannini, A. and B. Turtelboom (1994) divide models into three groups. The first are standard two-period portfolio balance models set in a general equilibrium, where domestic and foreign interest rates, and changes of the exchange rate, are jointly determined. Optimal holdings of assets and currencies are also determined simultaneously. Usually domestic demand for assets are postulated and not derived from any explicit underlying optimisation problem.[8] These models carry the danger of misspecification because their

[8] See, for instance, Branson, W. H. and D. W. Henderson (1983), and Cuddington, J. (1983).

ad hoc relationships have doubtful theoretical justification. Further, they often suffer on empirical side from problems of multicollinearity (rates of return are collinear, especially when the expected future spot exchange rate is approximated by the forward exchange rate) and partial adjustment. Partial adjustment involves the inclusion of the lagged dependent variable on the right-hand side of the regression. Since it is difficult to determine the cost of adjustment of private financial portfolio, there is a justification problem for use of that mechanism. Estimates may also introduce unrealistic values for the cost and speed of adjustment (too high and too slow).

The second group of models can be called sequential portfolio balance models. Agents make their optimal decisions in two steps. First, they choose the optimal mix between monetary and non-monetary assets. Second, they choose between domestic and foreign currency holdings according to the liquidity services they deliver and the opportunity cost of monies. For liquidity services, the standard choice is a CES functional form. For opportunity costs, nominal interest rates or the expected rate of depreciation of the domestic currency are normally chosen.[9] Agenor, P. R. and M. S. Khan (1996) provide an elaborate example, whereby a two-step procedure is used to derive the currency substitution ratio. First, a representative agent performs an intertemporal optimisation of his utility subject to budget and cash-in-advance constraints to obtain the desired long-run currency composition. Second, in a multiperiod cost-of-adjustment framework, adopted from the buffer stock money approach, he minimises the quadratic loss function to determine the actual short-run ratio. The resulting currency substitution ratio depends on its own once-lagged value and forward-looking variables, a geometrically declining weighted sum of the opportunity cost variable, which include parallel market premium on foreign exchange, the rate of depreciation and foreign nominal interest rates. The model is tested on quarterly data using an errors-in-variable procedure for ten developing countries: Bangladesh, Brazil, Ecuador, Indonesia, Malaysia, Mexico, Morocco, Nigeria, Pakistan and the Philippines. This model performs better than previously used partial adjustment models and yields statistically significant coefficients. The empirical results imply the significance of currency substitution in determining domestic money demand in these countries.

[9] Examples can be found in Miles, M. A. (1978), Bordo, M. and E. Choudhri (1982), Bana, I. M. and J. Handa (1990).

In the third group, Giovannini, A. and B. Turtelboom (1994) place those models that start with a representative agent's intertemporal dynamic optimisation problem, usually with both monies entering the agent's utility function. Such dynamic optimisation-type models have the advantage of explicitly deriving domestic demands for assets from 'first principles.' Even so, these models can be criticised for their assumptions about liquidity services performed by domestic and foreign currencies, and for the inclusion of monies in the utility function.[10] In the most recent approach, the authors start from first-order conditions. Then, utilising cross-equations restrictions from the assumption of rational expectations, through the Generalised Method of Moments by Hansen, L. P. (1982), they recover the parameters of interest that characterise consumer preferences, e.g. real consumption, real domestic and foreign money balances and the elasticity of currency substitution. Explicitly accounting for uncertainty, the model by Bufman, G. and L. Leiderman (1993) with nonexpected utility approach allows for intertemporal substitution and risk aversion parameters to be estimated separately. As with the models in the second group, the CES assumption on the liquidity services provided by different currencies is standard.[11] Among its several advantages, CES specification allows for both the elasticity of currency substitution and the share of currency substitution in the production of liquidity services to be estimated. This is important because even in the presence of the high elasticity of currency substitution a low share of foreign currency in the production of liquidity services means that currency substitution is irrelevant.

Obviously, empirical models from the third group are superior to those from the first and the second groups, because they more closely replicate the underlying theoretical models.

Finally, apart from testing for the presence of currency substitution explicitly, many studies choose an indirect way of testing for the consequences of currency substitution. Researchers mainly concentrate on testing the stability of the demand for domestic money[12] and the behaviour of

---

[10] See Calvo, G. A. (1985), Marquez, J. R. (1987), Bufman, G. and L. Leiderman (1992 and 1993), Rojas-Suarez, L. (1992), Imrohoroglu, S. (1994 and 1996), McNelis, P. D. and C. Asilis (1992).

[11] See Bufman, G. and L. Leiderman (1992 and 1993), and Imrohoroglu, S. (1994 and 1996).

[12] Savastano, M. A., M. A. (1992); Arrau, P., J. De Gregorio, C. Reinhart, and P. Wickham (1991).

inflation.[13] It is standard to use a broad monetary aggregate (M2) when testing the stability of the domestic money demand, because narrower monetary aggregate (M1) estimates do not reveal any noticeable or statistically significant effects of currency substitution.

The stability of the domestic money demand was studied Arrau, P., J. De Gregorio, C. Reinhart, and P. Wickham (1991) in the sample of ten developing countries. They argue that financial innovation is the missing ingredient that causes a great deal of problems for econometric studies. They link financial innovation and dollarisation together, and apply a financial innovation variable in their specification of the domestic money demand equation. They show that for certain high-inflation countries (e.g. Argentina, Israel and Mexico) the inclusion of financial innovation variable helps solve all problems encountered by the standard domestic money demand specifications (such as forecasting, quality, autocorrelations of errors, unrealistic parameter values).

McNelis, P. D. and C. Asilis (1992) examine the stability of inflation. Their main findings are that under low transaction costs or an increasing degree of currency substitution, the dynamic paths of domestic inflation and real money balances are highly volatile, i.e. small variations in the level of currency substitution cause large variations in the rate of inflation. Their GARCH estimates of the simulated data are consistent with those of the real time-series for Argentina, Bolivia, Mexico and Peru.

Rojas-Suarez, L. (1992) tests the hypothesis that currency substitution is an important channel of transmission of domestic fiscal and monetary policies to the behaviour of inflation rate in Peru. To test this, she uses a VAR representation of a dynamic equation for inflation rate that includes the lagged ratio of domestic to foreign money (the standard measure for the level of currency substitution) as an explanatory variable. The idea is that while government is using the inflation tax to finance an unsustainable budget deficit, the economic agents do their best to avoid this kind of taxation by increasing the velocity of domestic money and by switching to the use of foreign currency. To keep up with their needs for finance and to counter-attack the agents' efforts, the government needs to increase the rate of monetary growth, thus, there is a potential role for currency substitution in the monetary transmission mechanism. Indeed, empirical estimates show that the coefficient on the lagged currency substitution variable rose sig-

[13] McNelis, P. D. and C. Asilis (1992); Rojas-Suarez, L. (1992).

nificantly during the recent hyperinflation episode in Peru (August 1985 to June 1990). The increase indicates that agents speed up their adjustment (through the use of foreign currency) as inflation accelerates.

Concluding the section we can notice that the most prominent themes related to the costs and benefits of currency substitution in the recent literature are: disciplinary aspects of currency substitution, effects of currency substitution on the stability of the domestic banking system, effects of currency substitution on domestic output and growth rate, and the welfare effects of currency substitution. As these questions are not directly linked to econometric estimations of currency substitution we would only mention a few important contributions.

Sturzenegger (1992 and 1997) deals with welfare effects of currency substitution. His main result is that inflation tax is highly regressive and hits harder the lower income agents. This is due to existence of a fixed cost of switching to inflation-proof transaction technologies. Therefore, currency substitution should not be favoured when considered from a welfare point of view.

The disciplinary aspect of currency substitution is considered by Canzoneri and Diba (1992), Cukierman, Kiguel and Liaviatan (1992). First paper showed the role of currency substitution for correction of inflationary bias cased by national governments considerations over seigniorage revenues. Second stressed the cost of reneging as the main reason, which prevent policymakers from committing strongly to the chosen exchange rate policy in the presence of currency substitution.

# 3 Data and Methodology

The data sample was compiled from various sources. The time series for government expenditures came from two World Wide Web (WWW) data sources: the Central Statistical Bureau of Latvia and Latvia's Ministry of Finance. Consumer price index data are taken from IMF *International Financial Statistics* monthly publications. The rest of data, unless stated otherwise, has been provided by the Bank of Latvia Monetary Reviews, which are published quarterly and posted on the Web. These reviews contain all the major economic data on Latvia. All the time series, with the exception of the interbank overnight lending rate and time series related to the nominal gross domestic product, start on January 1993 and end on June 1999, and hence, cover 78 monthly observations. The nominal gross domestic product time series runs from the first quarter of 1993 to the second quarter of 1998.

Why this sample? Data prior to 1993 is poorly recorded, and more important, Latvia had not yet achieved full monetary independence. During 1992, the Russian rouble and Latvia's national currency circulated side by side, and there is no reliable data on their relative shares in the total money supply. Therefore, econometric analysis related to currency substitution needs to be done on data after 1992. The data sample finishes in June 1999 due to data availability at the time of the research. The sample size is optimal in the sense that, even after taking first and second differences from time series, we are still left with more than a full six years of data, which is very important for modelling and adjusting for seasonal effects. Seasonality is strongly present in time series of inflation and government expenditures. As a technical reference for modelling seasonality, the book edited by Hylleberg, S. (1992) was consulted. We decided to apply ARIMA X-11 CENCUS II method[14] of seasonal adjustment to government expenditures time series only, because testing for the presence of seasonality in inflation time series produced only weak evidence of seasonality. Note that seasonal adjustment can affect the power of cointegration tests, although cointegration vectors themselves are invariant to this transformation.[15]

Can we trust data on transition economies? Put shortly, no. The main reasons are poor accounting and reporting practises, as well as the constantly changing methodologies of national statistics. These and other numerous reasons are well documented in, for example, Bartholdy, K. (1996) or *Economic Survey of Europe in 1993-1994*. Typical for social science is an acknowledgement that it is not possible to recreate a better quality time series. It is fully applicable here, and we are forced to work with the data we have.

Let's take a closer look at the major time series. Note that, unless stated otherwise, a natural logarithm transformation was applied to all time series except the interest rate time series. Following Savastano, M. A.

[14] The robustness of X-11 Census II method for single time series seasonal adjustment is widely known and accepted, see, for example, Engle, R.F. (1992) for comparison with other methods.

[15] For details see Ericsson, N. R. (1998, p. 299) and Ericsson, N. R., Hendry, D. F. and H-A. Tran (1994, pp.: 179-224).

(1992), we adopt the following definition for the measure of currency substitution. Currency substitution is defined by the ratio of foreign currency deposits (FCD) to M2D monetary aggregate. M2D is the sum of M1 and time deposits in lats (the national currency of Latvia), where M1, in turn, is the sum of currency in circulation and demand deposits in lats. Therefore, M2D is a measure of domestic money supply. This measure of currency substitution is only a proxy for a real level of currency substitution in the economy, but it gives a lower bound for the level of currency substitution. Currency substitution ratio and its components are presented on Figure 1 and Figure 2 respectively, see Appendix B. Graphics, where all graphics is collected. These are original time series (no transformations are applied) running from January 1993 until June 1999. M2D and FCD are in millions of lats and currency substitution ratio times 100% shows the relative size of FCD to M2D in percentage. We observe the following evolution of currency substitution ratio. We enter 1993 with a high level of currency substitution, around 58%. This reflects high level of uncertainty at the onset of reforms and low degree of confidence in the newly established national currency. Gradually, sound economic policies and a firm monetary stance by the Bank of Latvia helps change the situation. The level of currency substitution falls significantly by early 1994 to around 38%. The fall is steep as most members of the public prefer not to hold foreign currency. Moreover, the newly established commercial banks have only rudimentary facilities for dealing with foreign currencies. Around May 1995, the first large banking crisis arrives. Due to fraudulent behaviour by the top management, the largest commercial bank in Latvia, *Banka Baltija*, goes bust. This leads to the bankruptcy of many other smaller commercial banks, as well as a contraction of GDP. With the collapse of public confidence, currency substitution jumps back to its old level of 58%. Again, the government and monetary authorities take a firm stance, refusing to bail out the f ailing banks. This helps reverse the situation, and by the end of 1995 the currency substitution level is down to around 48%. In the period from January 1996 to the end of summer 1997, we observe the turbulent behaviour of the currency substitution level, which fluctuates within a range of 43% and 51%. After autumn 1997, we observe a steady, but slow, decline in the level of currency substitution, which falls to 40% at the beginning of 1999. It is worth noting that the trend of this second decline is much flatter than that of the first decline in 1993. This may indicate a significantly increased persistence in the phenomenon of currency substitution, and the presence of hysteresis effect. This can be partly explained by the fact the public is now in the habit of using foreign currencies, as well as developments in the financial markets. Nevertheless, this level of currency substitution is very high, especially, taking into account good track record of Latvia's monetary authorities, improving economic conditions and single-digit inflation. It remains to be seen whether the declining trend of the level of currency substitution will continue until it meets natural limits, or the abnormally high level of currency substitution will persist. A timeline of major political and economic events in Latvia is provided in Appendix A. Timeline of major political and economic events in Latvia in 1991-1999.

We turn now to methodological issues. The debate on what is econometrics and how to use it has simmered since the 1970s, and no consensus is in sight. Nevertheless, some general agreements on model specification methodology are in place. These points of consensus are:

1. The important role of economic theory as a guidance to model specification;
2. Model residuals should be white noise;
3. General-to-specific testing down approach is preferred to attempts to cure a simple but misspecified model;
4. Misspecification tests should be performed simultaneously and should be taken into account;
5. The performance of a model on the out-of-sample data set is an important criteria; and,
6. Encompassing test should be reported whenever possible, and the path by which a researcher came to the selected specification should be exposed as fully as possible.

A brief summary of major viewpoints is presented in Kennedy, P. (1998, pp.: 73–90), and a fuller account of different views on econometric methodology may be found in the brilliant book edited by Granger, C. W. J. (1990). We shall follow 'the London School of Economics methodology' guidelines, which blend together time series methods and economic theory, and whose main proponent is Professor David Hendry.

The formal model building process can be divided into four steps, as in Pagan, A. R. (1990). First, we formulate a general unrestricted model (GUM), which includes all variables suggested by and consistent with economic theory. We restrict dynamics, i.e. lag length, as few as possible in a view of a sample size limitation. Second, we reparameterize the model to near orthogonal variables taking care of interpretability issue. For example, the regression $Y(t) = \beta_0 + \beta_1*X(t) + \beta_2*X(t-1) + \varepsilon(t)$ most probably will suffer from collinearity problems because of high correlation between regressors $X(t)$ and $X(t-1)$. This problem, however, can be easily avoided by a one-to-one transformation to the following regression form $Y(t) = \alpha_0 + \alpha_1*\Delta X(t) + \alpha_2*X(t-1) + \varepsilon(t)$, where $\alpha_0 = \beta_0$, $\alpha_1 = \beta_1$, $\alpha_2 = \beta_1 + \beta_2$, and the correlation between regressors is very low, i.e. they are nearly orthogonal. Third, we simplify the model by deleting statistically insignificant variables and combining them into interpretable combinations. The fourth, and last, step is analysis of residuals and predictive performance of the model. Following the building stage the next six criteria are used for model selection, as by Gilbert, C. L. (1990). First, the model should be data admissible, for example, unemployment rate values should be between 0 and 1; positivity restrictions have to be met. Second, the model should be consistent with some theory. Third, regressors should be at least weakly exogenous, with strong exogeneity necessary for forecasting exercise. Failure to have weakly exogenous regressors can seriously impair the efficiency and unbiasedness of the estimators in small samples, especially, for non-stationary, I(1) time series.[16] If weak exogeneity cannot be guaranteed, then the Instrumental Variable (IV) method should be applied for estimations, or system modelling should be committed. Fourth, estimated parameters should exhibit constancy over the sample. This is especially important if we are planning to use our model for forecasting purposes. Fifth, the model should be data coherent, i.e. model should have white noise errors. Sixth, the model should encompass a wide range of rivals, or, in case of a single equation linear model, it should exhibit variance dominance. A recent set of papers by Ericsson, N. R., Hendry, D. F. and G. E. Mizon (1998), Ericsson, N. R. (1998), Hendry, D. F. and G. E. Mizon (1998) provides a fresh and expanded exposition of these issues, including more theoretical elaboration, practical examples and references, with a special emphasis of their relevance to policy analysis.

[16] This happens as information gets lost when a conditional model is used instead of the system in the presence of a weak exogeneity failure, see Banerjee, A., Donaldo, J., Galbraith, J. W. and D. F. Hendry (1993, pp.: 244-52, 268, 288-91). More potential troubles of invalid exogeneity assumption are exposed in Ericsson, N. R., Hendry, D. F. and G. E. Mizon (1998, pp.: 370-2).

Using Hendry's language (1995, pp.: 544–547), we place our approach somewhere between *theory-driven approaches* and *data-driven approaches*. That is, while being guided by the economic theory on the set of possible explanatory variables and their relationships, we do not reject data evidence that some of these variables are not significant, and some others not suggested by theory should be added. Also, in interpreting results of econometric analysis for small samples of poor quality data contaminated by structural breaks (as our sample is), special care is needed before making definitive conclusions. It is very plausible that this kind of data set is unable to discriminate for the subtle effects we are searching to be estimated, for example, the role of volatility in determining the level of currency substitution.

# 4 Univariate modelling

We now turn to a univariate modelling approach for currency substitution phenomenon. The purpose of a univariate time series modelling is, as stated in Harvey, A. C. (1990a and 1990b), to explain the behaviour of the variable using its past observations only. In other words, we try to explain the salient features of the time series under investigation without reference to any possible explanatory variables. The resulting model can be used as a benchmark model, against which larger models with explanatory variables should be tested. Their performance in the sample and forecast accuracy out of the sample must be at least slightly better than those of a benchmark model, otherwise they should be rejected on the basis of the principle of parsimony. This strict principle of forecasting performance, however, may not need to be applied to cases where the goal is to develop a structural model to capture the relationships among different variables.

The methods of a univariate modelling approach was greatly shaped by Box-Jenkins ARIMA methodology in 1970s. Modern technical references for time series analysis can be found in Hamilton, J. D. (1994) and Enders, W. (1995). Bearing upon this influence, our analysis starts from reviewing autocorrelation functions of the variables under investigation. Figure 3 and Figure 4 present an autocorrelation and partial autocorrelation functions for currency substitution ratio respectively, together with the values of standard errors and Box-Ljung statistics. As suggested from these figures, currency substitution is a simple autoregressive process of order one. However, extreme caution should be exercised when choosing the order of the process. It is advisable to start with a more general model and later test it down. Also visual examination of CS time series reveals a number of breaks. These discontinuities in the process impact on its memory horizon by shortening it. All this suggests to use impulse dummy variables for clearly identified breaks in CS time series, and to start with autoregressive process of higher order than one. Direct estimations indeed coffirm this guess: the CS ratio is well represented by the second order autoregressive process.[17]

*Table 1 Estimation results of AR(2) model for CS ratio*

**Modelling LCS by OLS**
The present sample is: 1993 (3) to 1999 (6)

| Variable | Coefficient | Std.Error | t-value | t-prob | HCSE | PartR^2 |
|---|---|---|---|---|---|---|
| Constant | -0.061189 | 0.035916 | -1.704 | 0.0929 | 0.044078 | 0.0398 |
| LCS_1 | 0.74083 | 0.070161 | 10.559 | 0 | 0.082375 | 0.6143 |
| LCS_2 | 0.18807 | 0.071093 | 2.645 | 0.0101 | 0.077044 | 0.0909 |
| D93dec | -0.29315 | 0.043556 | -6.73 | 0 | 0.009201 | 0.3929 |
| D95may | 0.37188 | 0.043839 | 8.483 | 0 | 0.008471 | 0.5069 |
| D95dec | -0.19213 | 0.044485 | -4.319 | 0.0001 | 0.01559 | 0.2104 |

R2 = 0.879687, F(5,70) = 102.36 [0.0000], $\sigma$ = 0.0428337, DW = 2.03
RSS = 0.1284310973 for 6 variables and 76 observations

Diagnostics tests

| | |
|---|---|
| AR 1- 5 F( 5, 65) = | 1.0107 [0.4187] |
| ARCH 5 F( 5, 60) = | 1.4491 [0.2200] |
| Normality Chi^2(2)= | 4.0707 [0.1306] |
| Xi^2 F( 7, 62) = | 1.8864 [0.0870] |
| Xi*Xj F( 8, 61) = | 1.7464 [0.1058] |
| RESET F( 1, 69) = | 1.3005 [0.2581] |

[17] The results here and below were obtained using PcGive version 9.10 (see Hendry, D. F. and J. A. Doornik (1996)), and PcFiml version 9.10 (see Doornik, J. A. and D. F. Hendry (1997)).

Where LCS stands for natural logarithm transformation of the original currency substitution time series, LCS_1 is the value of currency substitution ratio lagged once, i.e. LCS(t-1), D93dec stands for impulse dummy variable for December 1993[18], RSS is residual sum of squares, and the rest of the notations and definitions are explained in Appendix C. Econometric tests. The diagnostics test for the model does not reveal any problems or misspecification. Model graphic analysis is presented on Figure 5, Figure 6, and Figure 7. As can be seen, recursive estimates show no problems with parameters constancy over the estimated sample. Residuals autocorrelation and partial autocorrelation functions are presented in Figure 9 and Figure 10. As expected, they behave like a white noise process.

The dynamics model for currency substitution can be solved with respect to long run horizon properties.

**Solved Static Long Run**

| | | | | |
|---|---|---|---|---|
| LCS = | -0.8606 | -4.123 D93dec | +5.23 D95may | -2.702 D95dec |
| (SE) | (0.08195) | (2.726) | (3.444) | (1.951) |

The Static Long Run solution (neglecting dummies) gives the value of CS ratio around 42%.[19]

Another important dynamic characteristic of the model, dynamic multiplier, can be calculated. The collection of dynamic multipliers for times t, t+1, t+2, … is the impulse response function of the model. It shows the evolution of CS ratio in response to a unit change in innovation (a unit shock). Following Hamilton, J. D. (1994, Ch.1), it can be shown that in our case the expression for dynamic multiplier is given by the following equation

[18] This dummy reflects the strong rise in confidence in a newly introduced national currency. Next dummy for May 1995 reflects the banking crisis events, and dummy for December 1995 reflects the omission from accounting of the failed banks.
[19] CS(%)=exp(-0.86)*100%=42%.

**Equation 1 AR(2) model for CS and its dynamic multipliers**

$$CS_t = 0.74 \cdot CS_{t-1} + 0.19 \cdot CS_{t-2} + Const + Dummies + \varepsilon_t$$

$$\frac{dCS_{t+j}}{d\varepsilon_t} = 0.18 \cdot (-0.20)^j + 0.82 \cdot (0.94)^j, j = 0,1,2...$$

As can be seen from Figure 11, the impact eventually dies out. After 24 months less than 20% of the initial shock remains. This kind of behaviour is in sharp contrast with the behaviour of non-stationary processes such as random walks, where the impact of a shock does not die out no matter how long ago the event took place. We would say such a process has an infinitely long memory; quite distinct from the short memory of the CS ratio.

Finally, we checked this model forecast for accuracy. We take a year of data, twelve monthly observations, out of sample for testing.

*Table 2 Forecast estimates of AR(2) model of CS*

**Modelling LCS by OLS**
The present sample is: 1993 (3) to 1999 (6) **less 12 forecasts**
The forecast period is: 1998 (7) to 1999 (6)

| Variable | Coefficient | Std.Error | t-value | t-prob | HCSE |
|---|---|---|---|---|---|
| Constant | -0.0711 | 0.038108 | -1.866 | 0.0671 | 0.045663 |
| LCS_1 | 0.7402 | 0.073188 | 10.114 | 0 | 0.081707 |
| LCS_2 | 0.1718 | 0.073057 | 2.352 | 0.0221 | 0.073364 |
| D93dec | -0.2945 | 0.04379 | -6.725 | 0 | 0.009322 |
| D95may | 0.36538 | 0.044302 | 8.247 | 0 | 0.008401 |
| D95dec | -0.19147 | 0.044763 | -4.277 | 0.0001 | 0.016015 |

R^2 = 0.881197, F(5,58) = 86.041 [0.0000], $\sigma$ = 0.0430326, DW = 2.01
RSS = 0.1074044994 for 6 variables and 64 observations

Analysis of 1-step forecasts

| Date | Actual | Forecast | Y-Yhat | Forecast SE | t-value |
|---|---|---|---|---|---|
| 1998 7 | -0.80478 | -0.79946 | -0.00531 | 0.0433975 | -0.12245 |
| 1998 8 | -0.82448 | -0.80446 | -0.02002 | 0.0433998 | -0.46131 |
| 1998 9 | -0.87516 | -0.81965 | -0.05552 | 0.0434344 | -1.27817 |
| 1998 10 | -0.87046 | -0.86054 | -0.00992 | 0.0436459 | -0.22727 |
| 1998 11 | -0.90858 | -0.86577 | -0.04281 | 0.043625 | -0.98132 |
| 1998 12 | -0.90434 | -0.89318 | -0.01116 | 0.0437826 | -0.25491 |
| 1999 1 | -0.92336 | -0.89659 | -0.02678 | 0.0438246 | -0.61097 |
| 1999 2 | -0.84037 | -0.90994 | 0.069574 | 0.0438887 | 1.58524 |
| 1999 3 | -0.92941 | -0.85178 | -0.07763 | 0.0440675 | -1.76157 |
| 1999 4 | -0.94839 | -0.90342 | -0.04496 | 0.0440923 | -1.01976 |
| 1999 5 | -0.98345 | -0.93277 | -0.05068 | 0.0440857 | -1.1495 |
| 1999 6 | -0.94071 | -0.96198 | 0.021277 | 0.044377 | 0.479448 |

**Tests of parameter constancy over: 1998 (7) to 1999 (6)**

Forecast Chi^2(12)= 11.985 [0.4469]

Chow F(12, 58) = 0.94622 [0.5090]

**Diagnostics tests**

| | | |
|---|---|---|
| AR 1- 5 F( 5, 53) = | 0.83985 | [0.5275] |
| ARCH 5 F( 5, 48) = | 1.0631 | [0.3925] |
| Normality Chi^2(2)= | 5.4725 | [0.0648] |
| Xi^2 F( 7, 50) = | 1.9317 | [0.0840] |
| Xi*Xj F( 8, 49) = | 1.8569 | [0.0888] |
| RESET F( 1, 57) = | 3.1148 | [0.0829] |

Parameters are constant over the forecast period. The average forecast standard error is 4.38% and never exceeds 4.44%, see Figure 8. This is not a bad result for such a simple model. Additionally, we present 3-step ahead forecasts (i.e. a quarter ahead forecasts which can be of particular interest to policy makers), and pure dynamic forecast for this model, see Figure 12 and Figure 13. Their performance is quite satisfactory; the forecast variable hardly ever crosses error bounds.

We now move to the next stage of finding explanatory variables that may be helpful in creating a better model of currency substitution phenomenon.

# 5 Multivariate modelling

For the initial choice of candidates for explanatory variables, standard economic theory and a few theoretical observations in my PhD thesis (Sarajevs, V. (1999)) give some guidance. We choose the following set of plausible explanatory variables and their lags: the currency substitution ratio, the real effective exchange rate, inflation rate, net foreign assets of central bank, share of total trade (export plus import) to nominal gross domestic product (GDP), share of government expenditures to nominal GDP, real spread on long term deposits in lats and foreign currency, spread on short term credits, volatility of government expenditure share and dummies for

*Table 3 Data Description*

| Notation | Definition | Units | Publication source | Stationary |
|---|---|---|---|---|
| M2D | Domestic money supply. Sum of currency in circulation and demand and time deposits in lats. | Million, LVL | Bank of Latvia, Monetary Review (quarterly) | No |
| FCD | Foreign currency deposits. | Million, LVL | Bank of Latvia, Monetary Review (quarterly) | No |
| CS | Currency substitution ratio, FCD/M2D. | N/A | Calculated | Yes |
| RER | Real effective exchange rate | Index number | Bank of Latvia, Monetary Review (quarterly) | Yes |
| LDP | Average monthly inflation rate. | % | Calculated from IMF IFS price index | Yes |
| CBNFA | Central bank net foreign assets. | Million, LVL | Bank of Latvia, Monetary Review (quarterly) | No, I(1) |
| TT | Share of total trade in nominal GDP. | Million, LVL | Calculated from Bank of Latvia, Monetary Review (quarterly) | Yes |
| SALZ | Share of government expen- | Million, | Central Statistical Bureau of | No, I(1) |

| | | | | |
|---|---|---|---|---|
| | ditures (central government basic budget) in nominal GDP. Seasonally adjusted. | LVL | Latvia and Ministry of Finance. Calculated using Census II X-11 ARIMA method. | |
| RspLT | Real spread on long term deposits in lats and foreign currency. | % | Calculated from Bank of Latvia, Monetary Review (quarterly) | No, I(1) |
| STcrS | Spread on short term credits in lats and foreign currency. | % | Calculated from Bank of Latvia, Monetary Review (quarterly) | Yes |
| VarZ | Volatility of government expenditures. | N/A | Calculated as squared residuals from AR(4) model of SALZ, multiplied by 100. | Yes |
| **Note**. Unless stated otherwise, for any variable X: LX means natural logarithm transformation of X, DX means first difference of X, DX(t)=X(t)-X(t-1). | | | | |

structural breaks. Plots of their levels and first differences are presented in Figure 14 and Figure 15. Also see Table 3 Data Description below. [20]

Some possible justifications for choosing these variables are as follows. The real effective exchange rate is included, because, in dealing with foreign currencies, we would expect economic agents to use some kind of exchange rate to convert their money holdings to a common denomination before the decision-making process. Since agents use a number of currencies, and inflation rate enters our analysis explicitly as a separate variable. Thus, the real effective exchange rate seems to be the best indicator linking domestic and foreign economies. The rate of inflation has always been an important determinant of agent decision-making as it reflects the opportunity cost of holding money balances. The net foreign assets of the central bank are included because the Bank of Latvia has pegged the lat to the SDR. Thus. The BoL spends considerable energy maintaining adequate reserves in prime foreign currencies (USD, DEM, GBP), and often intervenes in foreign exchange markets. The share of total trade to GDP is the general indicator of openness of the economy, which often increases reliance on foreign currencies. Spreads on deposits and credits are another

[20] Table includes M2D and FCD because they are CS ratio components. A summary of the results from stationarity/unit root testing is presented here only for convenience. The actual test results are presented in Table 4 Unit Root tests.

important indicator of the relative value of currencies for households and firms, respectively. Since households are the major source of foreign currency, and firms only use it to finance short-term investments and trading activities, we can expect both spreads to be important in the short run, and only the deposit spread in the long run. The share of government expenditures to GDP may be significant depending on how the government chooses to finance its debt. For example, printing more money or raising taxes will both have serious implications for the economy. Volatility of the share of government expenditures to GDP reflects the level of risk and general instability in the economy, which are partly represented by the behaviour of inflation rate and real effective exchange rate. We would normally expect CS ratio to rise when instability increases.

## 5.1 Pre-testing: Unit root, Granger causality, Weak exogeneity

Before of modelling with the general unrestricted model (GUM), we conduct two sets of tests of our variables. One is for the presence of unit roots and order of integration. The other is the test of Granger causality, which assesses the usefulness of explanatory variables for forecasting of CS ratio and vice versa. Later, we examine the issue of weak exogeneity. These tests are important, because if some of variables are non-stationary I(1) processes then we get into spurious regression results. Moreover, long-run properties of the system with non-stationary variables that are neither differenced nor combined into cointegrated vectors can be quite dubious. Granger causality tests can reveal the potential value of one variable in explaining other variables. After weak exogeneity is established, the results of Granger causality tests can utilised to assess the existence of strong exogeneity, which is necessary for multi-step ahead forecasting. Both sets of tests can alert for the presence of problems at the onset of the empirical modelling exercise.

The Augmented Dickey-Fuller test (ADF test) included in PcGive software was used to test for unit roots, see Appendix C. Econometric tests for details. Methodology of testing is from general to specific as advocated by Donaldo, Jenkinson, and Sosvilla-Rivero (1990) and explained in Enders (1995, pp. 256-8). Also we should notice that the ADF test, as other unit root tests, has very low power, and cannot distinguish between unit root and near unit root processes, or between trend stationary and drifting processes. The results are summarised in the following table (null hypothesis is unit root).

*Table 4 Unit Root tests*

**Unit-root tests 1993 (3) to 1999 (6)**
**Critical values: 5%=-2.9 1%=-3.517; Constant included**

| | t-adf | Beta Y_1 | sigma | lag | t-DY_lag | t-prob | F-prob | AIC |
|---|---|---|---|---|---|---|---|---|
| LCS | -2.8479 | 0.79850 | 0.071040 | 1 | -0.23607 | 0.8140 | | -5.2503 |
| LCS | -3.0832* | 0.79344 | 0.070586 | 0 | | | 0.8140 | -5.2759 |
| LTT | -3.2002* | 0.73340 | 0.10072 | 1 | -2.3382 | 0.0221 | | -4.5521 |
| LTT | -4.1159** | 0.66765 | 0.10372 | 0 | | | 0.0221 | -4.5062 |
| LDP | -3.7233** | 0.62949 | 0.011218 | 1 | -0.30592 | 0.7605 | | -8.9419 |
| LDP | -4.2393** | 0.61709 | 0.011149 | 0 | | | 0.7605 | -8.9669 |

**Unit-root tests 1993 (3) to 1999 (9). Extended sample.**
**Critical values: 5%=-2.898 1%=-3.514; Constant included**

| | t-adf | Beta Y_1 | sigma | lag | t-DY_lag | t-prob | F-prob | AIC |
|---|---|---|---|---|---|---|---|---|
| LCS | -3.1060* | 0.7888 | 0.070088 | 1 | -0.10748 | 0.915 | | -5.279 |
| LCS | -3.2830* | 0.78679 | 0.069637 | 0 | | | 0.915 | -5.304 |

**Unit-root tests 1993 (4) to 1999 (6)**
**Critical values: 5%=-2.9 1%=-3.519; Constant included**

| | t-adf | Beta Y_1 | sigma | lag | t-DY_lag | t-prob | F-prob | AIC |
|---|---|---|---|---|---|---|---|---|
| RspLT | -1.919 | 0.90445 | 9.0379 | 1 | 0.052537 | 0.958 | | 4.442 |
| RspLT | -1.9698 | 0.90503 | 8.9759 | 0 | | | 0.958 | 4.4154 |

**Unit-root tests 1993 (4) to 1999 (6)**
**Critical values: 5%=-2.9 1%=-3.519; Constant included**

| | t-adf | Beta Y_1 | sigma | lag | t-DY_lag | t-prob | F-prob | AIC |
|---|---|---|---|---|---|---|---|---|
| STcrS | -9.1675** | -0.03399 | 14.247 | 0 | 5.3394 | | | |
| VarZ | -7.5609** | 0.12565 | 0.58005 | 0 | -1.063 | | | |

**Unit-root tests 1993 (5) to 1999 (6)**
**Critical values: 5%=-2.901 1%=-3.52; Constant included**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| LCBN FA | -0.51063 | 0.99173 | 0.050459 | 3 | 1.2278 | 0.224 | | -5.908 |
| LCBN FA | -0.56969 | 0.99075 | 0.050641 | 2 | 0.16114 | 0.872 | 0.224 | -5.913 |
| LCBN FA | -0.58368 | 0.9906 | 0.050293 | 1 | 2.2871 | 0.025 | 0.468 | -5.94 |
| LCBN FA | -0.89433 | 0.98534 | 0.051749 | 0 | | | 0.091 | -5.896 |
| **Critical values: 5%=-3.47 1%=-4.085; Constant and Trend included** | | | | | | | | |
| LCBN FA | -2.6673 | 0.86745 | 0.04842 | 3 | 1.9231 | 0.059 | | -5.978 |
| LCBN FA | -2.2381 | 0.88976 | 0.049358 | 2 | 0.68952 | 0.493 | 0.059 | -5.952 |
| LCBN FA | -2.1482 | 0.89702 | 0.049173 | 1 | 2.549 | 0.013 | 0.131 | -5.972 |
| LCBN FA | -1.9362 | 0.90381 | 0.051041 | 0 | | | 0.017 | -5.911 |
| **Unit-root tests 1993 (5) to 1999 (6)<br>Critical values: 5%=-3.47 1%=-4.085; Constant and Trend included** | | | | | | | | |
| LRER | -4.8017** | 0.83455 | 0.024737 | 3 | 0.86915 | 0.388 | | -7.321 |
| LRER | -4.7415** | 0.838 | 0.024693 | 2 | 2.0004 | 0.049 | 0.388 | -7.337 |
| LRER | -4.3675** | 0.84997 | 0.025217 | 1 | 4.4418 | 0 | 0.101 | -7.308 |
| LRER | -4.5170** | 0.82747 | 0.028349 | 0 | | | 1E-04 | -7.087 |
| **Unit-root tests 1993 (5) to 1999 (6)<br>Critical values: 5%=-2.901 1%=-3.52; Constant included** | | | | | | | | |
| SALZ | -1.6159 | 0.91167 | 0.1122 | 3 | -0.9718 | 0.335 | | -4.31 |
| SALZ | -1.7907 | 0.90336 | 0.11215 | 2 | 0.74512 | 0.459 | 0.335 | -4.323 |
| SALZ | -1.6983 | 0.90982 | 0.1118 | 1 | -5.1927 | 0 | 0.476 | -4.342 |
| SALZ | -2.649 | 0.8411 | 0.13041 | 0 | | | 0 | -4.048 |

The conclusion is that all variables are stationary and integrated of order zero, I(0), except for the real spread of long-term deposits (RspLT), the log of central bank net foreign assets (LCBNFA) and the seasonally adjusted (by Census II X-11 ARIMA method) share of government expenditures to nominal GDP (SALZ), which are non-stationary and are integrated of order one, I(1). Other notation used is LTT – log of total trade share in GDP, LDP – inflation rate, STcrS – short term credit spread, VarZ – volatility of the share of government expenditures, LRER – log of the real effective exchange rate. The hypothesis of the unit root in the CS ratio time series was rejected only at 5% significance level, both in the original and extended sample sizes. Nevertheless, bearing in mind the results of a univariate time series modelling for the CS ratio, we argue that it is a stationary, rather than a non-stationary, process. Also if we regress CS one constant and three dummies for structural breaks, as used in Table 1, then saved residuals from this regression do not contain the unit root even at 1% significance level. Finally, the absence of unit root in CS time series is consistent with the theoretical knowledge that its values must belong to a closed interval between zero and one.

A bivariate Granger causality test is performed as explained in Hamilton (1994, Ch. 11, p. 304). Hendry, D. F. and G. E. Mizon (1998, p. 269) have highlighted several of the potential difficulties and controversies with Granger causality, so we note that our test is quite sensitive to the choice of lag length. We control for this problem using the minimum lag length required to avoid problems in the diagnostics tests. For the sake of brevity, tests are reported only for the variables, which fall into suspicion after initial testing round, and can be important for the issue of weak exogeneity. These variables are the log of the real effective exchange rate (LRER), the log of central bank net foreign assets (LCBNFA) and the seasonally adjusted share of government expenditures to nominal GDP (SALZ).

*Table 5 Bivariate Granger Causality test: LRER and LCS*

**Modelling LRER by OLS**
The present sample is: 1993 (5) to 1999 (6)

| Variable | Coefficient | Std.Error | t-value | t-prob | HCSE | PartR^2 |
|---|---|---|---|---|---|---|
| Constant | 0.24179 | 0.12086 | 2.001 | 0.0498 | 0.14114 | 0.0597 |
| LRER_1 | 1.3317 | 0.11045 | 12.057 | 0 | 0.1909 | 0.6977 |
| LRER_2 | -0.24535 | 0.18393 | -1.334 | 0.187 | 0.25872 | 0.0275 |
| LRER_3 | 0.11203 | 0.18951 | 0.591 | 0.5565 | 0.23317 | 0.0055 |
| LRER_4 | -0.25133 | 0.11575 | -2.171 | 0.0337 | 0.15021 | 0.0696 |
| D93dec | 0.091337 | 0.02775 | 3.291 | 0.0016 | 0.013227 | 0.1467 |
| D98sep | 0.09118 | 0.024031 | 3.794 | 0.0003 | 0.004091 | 0.186 |
| LCS_1 | -0.06575 | 0.042381 | -1.551 | 0.1258 | 0.033978 | 0.0368 |
| LCS_2 | -0.00293 | 0.056453 | -0.052 | 0.9587 | 0.049813 | 0 |
| LCS_3 | 0.057349 | 0.055172 | 1.039 | 0.3026 | 0.060264 | 0.0169 |
| LCS_4 | -0.0036 | 0.039233 | -0.092 | 0.9272 | 0.051806 | 0.0001 |

R^2 = 0.970991, F(10,63) = 210.88 [0.0000], $\sigma$ = 0.0238029, DW = 2.28
RSS = 0.03569434476 for 11 variables and 74 observations

**Diagnostics tests**

| | | |
|---|---|---|
| AR 1- 5 F( 5, 58) = | 1.8819 | [0.1115] |
| ARCH 5 F( 5, 53) = | 0.86947 | [0.5078] |
| Normality Chi^2(2)= | 3.8684 | [0.1445] |
| Xi^2 F(18, 44) = | 1.5686 | [0.1121] |
| RESET F( 1, 62) = | 0.24506 | [0.6223] |

**Wald test for linear restrictions: Subset**
**LinRes F( 4, 63) = 1.0528 [0.3874]**

**Zero restrictions on: LCS_1 LCS_2 LCS_3 LCS_4**

*Table 6 Bivariate Granger Causality test: LCBNFA and LCS*

**Modelling LCBNFA by OLS**
The present sample is: 1993 (5) to 1999 (6)

| Variable | Coefficient | Std.Error | t-value | t-prob | HCSE | PartR^2 |
|---|---|---|---|---|---|---|
| Constant | 0.090036 | 0.081308 | 1.107 | 0.2725 | 0.080282 | 0.0197 |
| LCBNFA_1 | 1.1518 | 0.064117 | 17.964 | 0 | 0.057236 | 0.841 |
| LCBNFA_2 | -0.14558 | 0.064202 | -2.268 | 0.0269 | 0.041352 | 0.0777 |
| LCBNFA_3 | 0.096554 | 0.059984 | 1.61 | 0.1126 | 0.04406 | 0.0407 |
| LCBNFA_4 | -0.10739 | 0.047965 | -2.239 | 0.0288 | 0.034272 | 0.0759 |
| LCS_1 | 0.044388 | 0.062268 | 0.713 | 0.4787 | 0.056889 | 0.0083 |
| LCS_2 | 0.036045 | 0.076952 | 0.468 | 0.6412 | 0.077936 | 0.0036 |
| LCS_3 | -0.02041 | 0.088237 | -0.231 | 0.8179 | 0.098721 | 0.0009 |
| LCS_4 | 0.00621 | 0.07619 | 0.082 | 0.9353 | 0.090967 | 0.0001 |
| D95may | -0.17151 | 0.037099 | -4.623 | 0 | 0.011768 | 0.2595 |
| D95aug | 0.15617 | 0.047139 | 3.313 | 0.0016 | 0.033197 | 0.1525 |
| D98sep | -0.11876 | 0.03651 | -3.253 | 0.0019 | 0.007231 | 0.1478 |
| D99may | 0.15791 | 0.037576 | 4.203 | 0.0001 | 0.012699 | 0.2245 |

R^2 = 0.99218, F(12,61) = 644.99 [0.0000], $\sigma$ = 0.0355623, DW = 1.88
RSS = 0.07714517966 for 13 variables and 74 observations

**Diagnostics tests**

| | | |
|---|---|---|
| AR 1- 5 F( 5, 56) = | 0.73324 | [0.6016] |
| ARCH 5 F( 5, 51) = | 0.54565 | [0.7408] |
| Normality Chi^2(2)= | 4.219 | [0.1213] |
| Xi^2 F(20, 40) = | 0.56342 | [0.9150] |
| RESET F( 1, 60) = | 0.15209 | [0.6979] |

**Wald test for linear restrictions: Subset**
**LinRes F( 4, 61) = 0.81253 [0.5221]**
**Zero restrictions on: LCS_1 LCS_2 LCS_3 LCS_4**

**Modelling DLCBNFA by OLS**
The present sample is: 1993 (5) to 1999 (6)

| Variable | Coefficient | Std.Error | t-value | t-prob | HCSE | PartR^2 |
|---|---|---|---|---|---|---|
| Constant | 0.010008 | 0.004914 | 2.037 | 0.0459 | 0.005111 | 0.0618 |
| DLCBNFA_1 | 0.19001 | 0.055502 | 3.424 | 0.0011 | 0.04649 | 0.1569 |
| DLCBNFA_2 | 0.033455 | 0.050517 | 0.662 | 0.5102 | 0.03922 | 0.0069 |
| DLCBNFA_3 | 0.12036 | 0.047117 | 2.555 | 0.0131 | 0.031929 | 0.0939 |
| D95may | -0.17719 | 0.03671 | -4.827 | 0 | 0.008355 | 0.27 |
| D95aug | 0.16596 | 0.046324 | 3.583 | 0.0007 | 0.034739 | 0.1692 |
| D98sep | -0.12118 | 0.035976 | -3.368 | 0.0013 | 0.005385 | 0.1526 |
| D99may | 0.14856 | 0.036946 | 4.021 | 0.0002 | 0.010687 | 0.2042 |
| DLCS_1 | 0.034793 | 0.061152 | 0.569 | 0.5714 | 0.052454 | 0.0051 |
| DLCS_2 | 0.058683 | 0.061119 | 0.96 | 0.3407 | 0.061787 | 0.0144 |
| DLCS_3 | 0.023854 | 0.073772 | 0.323 | 0.7475 | 0.093328 | 0.0017 |

R^2 = 0.589185 F(10,63) = 9.0354 [0.0000] \sigma = 0.0356551 DW = 1.90
RSS = 0.08009111775 for 11 variables and 74 observations

**Diagnostics tests**

| | | |
|---|---|---|
| AR 1- 5 F( 5, 58) = | 0.60879 | [0.6934] |
| ARCH 5 F( 5, 53) = | 0.48692 | [0.7845] |
| Normality Chi^2(2)= | 4.9436 | [0.0844] |
| Xi^2 F(16, 46) = | 0.30893 | [0.9935] |
| RESET F( 1, 62) = | 0.003073 | [0.9560] |

**Wald test for linear restrictions: Subset**
**LinRes F( 3, 63) = 0.3622 [0.7805]**
**Zero restrictions on: DLCS_1 DLCS_2 DLCS_3**

*Table 7 Bivariate Granger Causality test: SALZ and LCS*

**Modelling SALZ by OLS**

The present sample is: 1993 (5) to 1999 (6)

| Variable | Coefficient | Std.Error | t-value | t-prob | HCSE | PartR^2 |
|---|---|---|---|---|---|---|
| Constant | 0.1636 | 0.116 | 1.41 | 0.1635 | 0.11761 | 0.0316 |
| D95feb | -0.43579 | 0.078773 | -5.532 | 0 | 0.026909 | 0.3341 |
| D94feb | 0.33935 | 0.090949 | 3.731 | 0.0004 | 0.040051 | 0.1858 |
| D99apr | 0.26478 | 0.078899 | 3.356 | 0.0014 | 0.021502 | 0.1559 |
| D93nov | -0.32581 | 0.081816 | -3.982 | 0.0002 | 0.031313 | 0.2063 |
| SALZ_1 | 0.46422 | 0.08083 | 5.743 | 0 | 0.07924 | 0.351 |
| SALZ_2 | 0.38604 | 0.085433 | 4.519 | 0 | 0.099652 | 0.2508 |
| SALZ_3 | 0.023574 | 0.082766 | 0.285 | 0.7767 | 0.088408 | 0.0013 |
| SALZ_4 | 0.11992 | 0.077059 | 1.556 | 0.1248 | 0.075827 | 0.0382 |
| LCS_1 | 0.028086 | 0.13638 | 0.206 | 0.8375 | 0.093093 | 0.0007 |
| LCS_2 | -0.11877 | 0.18397 | -0.646 | 0.521 | 0.13016 | 0.0068 |
| LCS_3 | 0.059741 | 0.16712 | 0.357 | 0.722 | 0.16416 | 0.0021 |
| LCS_4 | 0.22636 | 0.13109 | 1.727 | 0.0893 | 0.16374 | 0.0466 |

R^2 = 0.925849 F(12,61) = 63.47 [0.0000] \sigma = 0.0745195 DW = 2.11

RSS = 0.3387427387 for 13 variables and 74 observations

**Diagnostics tests**

| | | |
|---|---|---|
| AR 1- 5 F( 5, 56) = | 1.8509 | [0.1178] |
| ARCH 5 F( 5, 51) = | 0.25516 | [0.9353] |
| Normality Chi^2(2)= | 0.63591 | [0.7276] |
| Xi^2 F(20, 40) = | 0.4129 | [0.9816] |
| RESET F( 1, 60) = | 1.4119 | [0.2394] |

**Wald test for linear restrictions: Subset**

**LinRes F( 4, 61) = 1.6821 [0.1657]**

**Zero restrictions on: LCS_1 LCS_2 LCS_3 LCS_4**

**Modelling DSALZ by OLS**
The present sample is: 1993 (5) to 1999 (6)

| Variable | Coefficient | Std.Error | t-value | t-prob | HCSE | PartR^2 |
|---|---|---|---|---|---|---|
| D95feb | -0.47392 | 0.078875 | -6.009 | 0 | 0.020227 | 0.3643 |
| D94feb | 0.33306 | 0.092832 | 3.588 | 0.0007 | 0.043084 | 0.1697 |
| D99apr | 0.24161 | 0.079023 | 3.057 | 0.0033 | 0.015479 | 0.1292 |
| D93nov | -0.31671 | 0.080415 | -3.938 | 0.0002 | 0.024418 | 0.1976 |
| Constant | -0.00905 | 0.009245 | -0.979 | 0.3312 | 0.009287 | 0.015 |
| DSALZ_1 | -0.50301 | 0.080531 | -6.246 | 0 | 0.089521 | 0.3824 |
| DSALZ_2 | -0.11728 | 0.086583 | -1.355 | 0.1804 | 0.12525 | 0.0283 |
| DSALZ_3 | -0.1118 | 0.076875 | -1.454 | 0.1508 | 0.081067 | 0.0325 |
| DLCS_1 | -0.04486 | 0.12979 | -0.346 | 0.7308 | 0.087067 | 0.0019 |
| DLCS_2 | -0.17968 | 0.14171 | -1.268 | 0.2095 | 0.086975 | 0.0249 |
| DLCS_3 | -0.14238 | 0.12938 | -1.1 | 0.2753 | 0.17327 | 0.0189 |

R^2 = 0.725545, F(10,63) = 16.655 [0.0000], σ = 0.0765128, DW = 2.04
RSS = 0.3688152203 for 11 variables and 74 observations

**Diagnostics tests**

| | | |
|---|---|---|
| AR 1- 5 F( 5, 58) = | 1.9796 | [0.0952] |
| ARCH 5 F( 5, 53) = | 0.09761 | [0.9921] |
| Normality Chi^2(2)= | 0.4072 | [0.8158] |
| Xi^2 F(16, 46) = | 1.1348 | [0.3538] |
| RESET F( 1, 62) = | 0.006255 | [0.9372] |

**Wald test for linear restrictions: Subset**
**LinRes F( 3, 63) = 0.78363 [0.5075]**
**Zero restrictions on: DLCS_1 DLCS_2 DLCS_3**

As can be seen, the CS ratio does not Granger cause any of the three variables, that is time series LRER, LCBNFA, and SALZ are exogenous with respect to the CS time series. Note that to tackle the problem of spurious regression for non-stationary time series, bivariate Granger causality tests were performed for both levels and differences of LCBNFA and SALZ time series.

Now we address the issue of weak exogeneity. If weak exogeneity holds, then one can apply a single equation analysis, otherwise single equation estimates and forecasts will be biased and inefficient. Other potential troubles in the case of invalid exogeneity assumptions are presented in Ericsson, N. R., Hendry, D. F. and G. E. Mizon (1998, pp.: 371-2). Our main interest is finding out whether the LRER, LCBNFA, and SALZ time series are weakly exogenous with respect to long-run parameters estimates of the CS equation. However, as noted by Hendry, D. F. and J. A. Doornik (1994, p. 5), assessing the validity of single equation analysis and enjoying its benefits "rather paradoxically first requires modelling" all variables under consideration as a system. This brings us to the problem of weak exogeneity testing.

There are two ways to test a weak exogeneity assumption, direct and indirect tests. As an indirect test for weak exogeneity, the test of model parameters constancy is quite revealing. To perform the test, one needs to run a recursive least square estimation of the model, plot the coefficients with their standard errors and visually examine the plots. These results of visual examination can be formally supplemented by the outcomes of the break-point Chow tests statistics. When model parameters exhibit constancy there is little to worry about, at least, from the empirical point of view.

Direct test for weak exogeneity can be conducted through the means of cointegration analysis. The basic idea behind this test is as follows. Consider a pure vector autoregression (VAR) with lag length $s$ for $n$ variables collected in vector $x_t$.

**Equation 2 VAR(s)**

$$x_t = \sum_{j=1}^{s} \Pi_j x_{t-j} + \varepsilon_t$$

When the data $x_t$ is non-stationary, I(1), it is common to transform the above VAR to error-correction model (ECM). Note that this one-to-one transformation can be applied to any VAR, whether the data are stationary or non-stationary.

**Equation 3 ECM**

$$\Delta x_t = \sum_{j=1}^{s-1} \Pi_j^* \Delta x_{t-j} + \pi x_{t-1} + \varepsilon_t$$

where the term $\pi x_{t-1}$ is responsible for the adjustment of variables to long-run equilibrium, from which they can deviate in the short-run. The differenced terms are responsible for a short-run dynamics. Hence, we have short-run and long-run dynamics separation, which is very useful in comprehending often complicated dynamic system structures. The $\pi$ matrix can be factored as a product of two matrices $\pi = \alpha\beta'$, so

Equation **3** can be rewritten as follows.

**Equation 4 ECM with cointegration vectors representation**

$$\Delta x_t = \sum_{j=1}^{s-1} \Pi_j^* \Delta x_{t-j} + \alpha \cdot (\beta' \cdot x_{t-1}) + \varepsilon_t$$

where the term $\beta' x_{t-1}$ represents cointegration vectors, i.e. the long-run equilibrium relationships among data, and the matrix $\alpha$ is the matrix, which "reveals the importance of each co-integrating combination in each equation, and is related to the speed of adjustment of each dependent variable to the associated disequilibria" Banerjee, A., Donaldo, J., Galbraith, J. W. and D. F. Hendry (1993, p. 268). Now, if there is a cointegration vector and it enters more than one equation in the system, then there is a weak exogeneity failure with respect to long-run parameters $\beta$. The equations appear to be inherently cross-linked, and, hence, should be modelled jointly; for more detailed exposition one should refer to Banerjee, A., Donaldo, J., Galbraith, J. W. and D. F. Hendry (1993, pp.: 261, 268-70, 288-91). Therefore, when there is only one cointegration vector and $\alpha$ is zero except for one entry, weak exogeneity holds, and a single equation estimation will not entail any loss of efficiency. Otherwise, variables should be modelled jointly in a system approach.

In our research, we start with direct testing approach. Large series of trials were conducted. However, no definite conclusions were possible to reach on the existence of cointegration and the number of cointegrating vectors. Nevertheless, some useful insights were gained, and the following comments are worth mention. First, our sample size of 78 observations imposed severe restrictions on the extent of system modelling. With that in mind, the length of four lags was chosen as sufficient to reflect the dynamic structure of the problem. Second, the idea of searching for a ***long***-run equilibrium relationship in a ***transition*** economy is an oxymoron. In particular, in economy such as Latvia, where transition processes are far from over, and there are some general doubts about the existence of stable economic mechanism, let alone the equilibrium relationships among economic variables residing in such a framework. Third, tests for cointegration are extremely sensitive to system specification, especially to restricted/unrestricted treatment of non-modelled deterministic variables such as constant, trend, and dummies. The comments on the low power of unit-root tests are applicable here as well, see Hamilton, J. D. (1994, p. 586). These three points explain why our failure with cointegration analysis was to be expected. Fourth, apart from two extreme outcomes: zero rank – no cointegration, and full rank – data is stationary, the most frequent outcome of cointegration analysis was that of one cointegrating relationship, which enters equations for LCS, LRER, and LCBNFA.[21] This reduces the potential system size to three equations. Furthermore, turning to the speed of adjustment coefficients ($\alpha$), we note that coefficients in LRER and LCBNFA equations are, although statistically significant, noticeably smaller in magnitude (around 4 times) than coefficients for the LCS equation. This means significantly slower adjustments for LRER and LCBNFA,

[21] In all cases, cointegration analysis is performed on VAR(4). The following cases deliver the aforementioned outcome. 1. Endogenous variables: LCS, LCBNFA, LRER, and SALZ. Deterministic variables: D93dec – unrestricted; D95may, D95dec, and Constant – restricted. As well as, D95may – restricted; Constant, D93dec, and D95dec – unrestricted. 2. Endogenous variables: LCS, LCBNFA, LRER, and SALZ plus the only I(1) variable left – RspLT. Deterministic variables: D95may – restricted; Constant, D93dec, and D95dec – unrestricted. Finally, if in case 2 we exclude LRER, which is statistically I(0), the outcome is still one cointegrating relationship, and only LCS and LCBNFA equations need to be modelled.

and from empirical point of view, their relative unimportance for short to medium-run forecasts.

## 5.2 Model Construction, Reduction, Evaluation

Bearing in mind these four caveats, we proceed with a single equation modelling in a fashion reminiscent of the Engle-Granger two-step cointegration procedure. First, we use a single equation static regression to form the error-correction (cointegration) vector from variables that seem important for long-run equilibrium. Second, we save residuals of this regression and test their stationarity[22] (property of being an I(0)-type variable), see Table 8. Third, we use these residuals in error-correction representation of initial autoregressive distributed lag (ADL) model of CS, see
Table 9 and Figure 18.

*Table 8 Error correction vector and its residuals test for stationarity*

**Modelling LCS by OLS**
**The present sample is: 1993 (3) to 1999 (6)**

| Variable | Coefficient | Std.Error | t-value | t-prob | HCSE | PartR^2 |
|---|---|---|---|---|---|---|
| Constant | 10.111 | 3.8216 | 2.646 | 0.0102 | 3.5334 | 0.0959 |
| LCBNFA | -0.13493 | 0.032958 | -4.094 | 0.0001 | 0.037723 | 0.2025 |
| LRER | -0.33277 | 0.094363 | -3.527 | 0.0008 | 0.089025 | 0.1586 |
| SALZ | -0.32856 | 0.059017 | -5.567 | 0 | 0.064824 | 0.3195 |
| LDP | -1.967 | 0.77905 | -2.525 | 0.014 | 0.74749 | 0.0881 |
| LTT | 0.35347 | 0.073698 | 4.796 | 0 | 0.072139 | 0.2585 |
| RspLT | 0.001259 | 0.000704 | 1.789 | 0.0782 | 0.000733 | 0.0463 |
| VarZ | 0.020362 | 0.01498 | 1.359 | 0.1787 | 0.015458 | 0.0272 |
| D93dec | -0.26082 | 0.088823 | -2.936 | 0.0046 | 0.046942 | 0.1155 |
| D95may | 0.24195 | 0.078887 | 3.067 | 0.0031 | 0.031455 | 0.1247 |

[22] When we are interested in stationarity and cointegretedness, the critical value for the ADF test for residuals differs from the standard, see Hamilton, J. D. (1994, pp.: 592-600) for explanations. The outcome of our unit root test satisfies Hamilton's criteria, see Hamilton, J. D. (1994, p. 766, Table B.9, Case 2 (Regression with constant term)).

R^2 = 0.653495, F(9,66) = 13.83 [0.0000], σ = 0.0748621, DW = 1.45
RSS = 0.3698860655 for 10 variables and 76 observations

**Diagnostics tests**

| | | |
|---|---|---|
| AR 1- 5 F( 5, 61) = | 1.874 | [0.1120] |
| ARCH 5 F( 5, 56) = | 1.4295 | [0.2279] |
| Normality Chi^2(2)= | 6.0315 | [0.0490] * |
| Xi^2 F(16, 49) = | 1.6156 | [0.1000] |
| Xi*Xj F(38, 27) = | 1.3044 | [0.2376] |
| RESET F( 1, 65) = | 0.30951 | [0.5799] |

**Unit-root tests 1993 (4) to 1999 (6)**
**Critical values: 5%=-1.945 1%=-2.594 no deterministic variables**

| Variable | t-adf | beta Y_1 | \sigma | Lag | AIC |
|---|---|---|---|---|---|
| **ECM** | -6.4753** | 0.27678 | 0.067901 | 0 | -5.3662 |

We also test the cointegration vector without dummy variables. In this case, the Normality test is passed with no problems, only ARCH(5) test fails badly. Thus the residuals still satisfy the cointegration criteria. Since there are no appealing arguments against restricting dummy variables to the cointegration vector, the initial formulation of cointegration vector, as given in Table 8 above, is accepted for further analysis. Error correction/cointegration vectors and models fit for both cases (with dummies and without dummies) can be seen on Figure 16 and Figure 17. As can be seen from Table , the long run level of the CS ratio depends positively on the volatility of government expenditure share (VarZ) (as expected when instability is increasing, economic agents prefer to hold more of foreign currency); on the total trade share (LTT) (more openness requires more foreign exchange); and on the real spread on long term deposits (RspLT). The CS ratio depends negatively on the net foreign assets of central bank (LCBNFA). Obviously, when the central bank buys on foreign exchange, it changes the balance of the foreign-to-domestic currency ratio in the direction of decrease. In the real effective exchange rate (LRER), a rise in LRER (defined here as *RER=P/(EP*)*) reduces international competitiveness, i.e. less export operations by trading firms, who need foreign currency for operations, and thus lower demand and return on households foreign currency funds, Finally, we have the share of government expenditures (SALZ) and the inflation rate (LDP). Notice that signs of RspLT and LDP are rather unexpected and puzzling. Later in Table 11, the short-run dynamics of DLCS, the sign of DRspLT is negative as expected, if we think about the real spread on long term deposits (RspLT) as an opportunity cost of currency substitution.

*Table 9 Initial estimates of ADL(4;4) model for CS in ECM form*

**Modelling DLCS by OLS**
**The present sample is: 1993 (6) to 1999 (6)**

| Variable | Coefficient | Std.Error | t-value | t-prob | HCSE | PartR^2 |
|---|---|---|---|---|---|---|
| Constant | -0.0045666 | 0.007989 | -0.572 | 0.5714 | 0.00879 | 0.0098 |
| DLCS_1 | 0.034227 | 0.14023 | 0.244 | 0.8087 | 0.16104 | 0.0018 |
| DLCS_2 | 0.22143 | 0.14511 | 1.526 | 0.1365 | 0.1622 | 0.0659 |
| DLCS_3 | -0.029228 | 0.13005 | -0.225 | 0.8236 | 0.13155 | 0.0015 |
| DLRER | 0.1625 | 0.38869 | 0.418 | 0.6786 | 0.40236 | 0.0053 |
| DLRER_1 | 0.3247 | 0.2942 | 1.104 | 0.2777 | 0.32307 | 0.0356 |
| DLRER_2 | -0.24836 | 0.32203 | -0.771 | 0.4461 | 0.41646 | 0.0177 |
| DLRER_3 | -0.45243 | 0.32218 | -1.404 | 0.1696 | 0.37191 | 0.0564 |
| DLCBNFA | 0.11954 | 0.21117 | 0.566 | 0.5752 | 0.2005 | 0.0096 |
| DLCBNFA_1 | 0.27287 | 0.18673 | 1.461 | 0.1534 | 0.17561 | 0.0608 |
| DLCBNFA_2 | -0.033388 | 0.1206 | -0.277 | 0.7836 | 0.12968 | 0.0023 |
| DLCBNFA_3 | -0.20913 | 0.10888 | -1.921 | 0.0634 | 0.10538 | 0.1006 |
| DSALZ | -0.067081 | 0.071945 | -0.932 | 0.3579 | 0.060129 | 0.0257 |
| DSALZ_1 | 0.069236 | 0.096807 | 0.715 | 0.4795 | 0.10651 | 0.0153 |
| DSALZ_2 | 0.083769 | 0.076409 | 1.096 | 0.2809 | 0.078157 | 0.0351 |
| DSALZ_3 | 0.042269 | 0.080333 | 0.526 | 0.6023 | 0.088366 | 0.0083 |
| DLDP | -0.53752 | 0.87848 | -0.612 | 0.5448 | 0.78704 | 0.0112 |
| DLDP_1 | 0.16923 | 0.87111 | 0.194 | 0.8472 | 0.82164 | 0.0011 |
| DLDP_2 | 0.7874 | 0.92403 | 0.852 | 0.4003 | 1.0047 | 0.0215 |
| DLDP_3 | 0.20806 | 0.82104 | 0.253 | 0.8015 | 0.75237 | 0.0019 |
| DLTT | 0.034104 | 0.080629 | 0.423 | 0.6751 | 0.082186 | 0.0054 |
| DLTT_1 | -0.1139 | 0.089391 | -1.274 | 0.2115 | 0.091967 | 0.0469 |
| DLTT_2 | -0.05804 | 0.082871 | -0.7 | 0.4886 | 0.081147 | 0.0146 |
| DLTT_3 | -0.068405 | 0.078096 | -0.876 | 0.3874 | 0.07181 | 0.0227 |
| DRspLT | -0.00061424 | 0.000929 | -0.661 | 0.513 | 0.001018 | 0.0131 |

| | | | | | | |
|---|---|---|---|---|---|---|
| DRspLT_1 | 3.07E-05 | 0.001086 | 0.028 | 0.9776 | 0.001123 | 0 |
| DRspLT_2 | 0.00057554 | 0.000934 | 0.616 | 0.5422 | 0.000922 | 0.0114 |
| DRspLT_3 | -0.0018083 | 0.000968 | -1.869 | 0.0706 | 0.000957 | 0.0957 |
| DSTcrS | 0.0008332 | 0.000553 | 1.506 | 0.1415 | 0.000557 | 0.0643 |
| DSTcrS_1 | 0.00088586 | 0.000538 | 1.645 | 0.1094 | 0.000542 | 0.0758 |
| DSTcrS_2 | -0.00057799 | 0.000593 | -0.975 | 0.3364 | 0.0006 | 0.028 |
| DSTcrS_3 | -0.00087636 | 0.000554 | -1.582 | 0.1232 | 0.000448 | 0.0705 |
| DvarZ | 0.015524 | 0.010642 | 1.459 | 0.1541 | 0.009184 | 0.0606 |
| DvarZ_1 | 0.016366 | 0.011999 | 1.364 | 0.1818 | 0.011609 | 0.0534 |
| DvarZ_2 | 0.019925 | 0.012445 | 1.601 | 0.1189 | 0.009952 | 0.0721 |
| DvarZ_3 | 0.011697 | 0.010581 | 1.105 | 0.2769 | 0.007894 | 0.0357 |
| ECM_1 | -0.29703 | 0.15128 | -1.963 | 0.0581 | 0.15257 | 0.1046 |
| D93dec | -0.25119 | 0.12593 | -1.995 | 0.0544 | 0.11482 | 0.1076 |
| D95may | 0.34916 | 0.086394 | 4.041 | 0.0003 | 0.078975 | 0.3311 |
| D95dec | -0.18384 | 0.0572 | -3.214 | 0.0029 | 0.040425 | 0.2384 |

R^2 = 0.852711, F(39,33) = 4.8987 [0.0000], $\sigma$ = 0.0417192, DW = 2.20
RSS = 0.05743621814 for 40 variables and 73 observations

**Diagnostics tests**

| | | |
|---|---|---|
| AR 1- 5 F( 5, 28) = | 1.5104 | [0.2184] |
| ARCH 5 F( 5, 23) = | 0.29373 | [0.9115] |
| Normality Chi^2(2)= | 0.24949 | [0.8827] |
| RESET F( 1, 32) = | 1.6719 | [0.2053] |

There are no signs of misspecification, and we proceed with model reduction. Despite all methodological considerations, the reduction process remains rather an art than a science, and its outcome is arbitrary to a certain extent. We apply the following major rule: Delete first variables with the worst t-statistics, and simultaneously keep the lag structure as symmetric and balanced as possible. Before proceeding with some transformations, we present intermediate results in Table 10.

.

*Table 10 Model reduction for DLCS, intermediate step*

**Modelling DLCS by OLS**
**The present sample is: 1993 (6) to 1999 (6)**

| Variable | Coefficient | Std.Error | t-value | t-prob | HCSE | PartR^2 |
|---|---|---|---|---|---|---|
| Constant | -0.0061804 | 0.004827 | -1.28 | 0.2058 | 0.005911 | 0.0289 |
| DLCS_2 | 0.20477 | 0.076696 | 2.67 | 0.01 | 0.10717 | 0.1147 |
| DLRER_1 | 0.34078 | 0.15339 | 2.222 | 0.0304 | 0.14761 | 0.0823 |
| DLRER_3 | -0.3806 | 0.17366 | -2.192 | 0.0327 | 0.22424 | 0.0803 |
| DLCBNFA_1 | 0.29907 | 0.091233 | 3.278 | 0.0018 | 0.095955 | 0.1634 |
| DLCBNFA_3 | -0.10709 | 0.057435 | -1.864 | 0.0676 | 0.053805 | 0.0594 |
| DLTT_1 | -0.088658 | 0.05057 | -1.753 | 0.0851 | 0.047676 | 0.0529 |
| DRspLT_3 | -0.0016792 | 0.000577 | -2.911 | 0.0052 | 0.000555 | 0.1335 |
| DSTcrS | 0.00061831 | 0.000328 | 1.886 | 0.0646 | 0.000338 | 0.0607 |
| DSTcrS_1 | 0.00080076 | 0.000344 | 2.326 | 0.0237 | 0.000281 | 0.0896 |
| DSTcrS_2 | -0.00062582 | 0.000354 | -1.765 | 0.083 | 0.000345 | 0.0536 |
| DSTcrS_3 | -0.0006545 | 0.000335 | -1.956 | 0.0555 | 0.000253 | 0.0651 |
| DvarZ | 0.005911 | 0.005877 | 1.006 | 0.3189 | 0.004424 | 0.0181 |
| ECM_1 | -0.1911 | 0.083009 | -2.302 | 0.0251 | 0.084042 | 0.0879 |
| D93dec | -0.17631 | 0.054405 | -3.241 | 0.002 | 0.044423 | 0.1603 |
| D95may | 0.30735 | 0.044121 | 6.966 | 0 | 0.023622 | 0.4687 |
| D95dec | -0.19284 | 0.038607 | -4.995 | 0 | 0.020077 | 0.3121 |
| DDSALZ | -0.04004 | 0.021923 | -1.826 | 0.0732 | 0.018321 | 0.0572 |

R^2 = 0.820042, F(17,55) = 14.743 [0.0000], $\sigma$ = 0.0357201, DW = 2.35
RSS = 0.07017572368 for 18 variables and 73 observations

**Diagnostics tests**

| | | |
|---|---|---|
| AR 1- 5 F( 5, 50) = | 1.3895 | [0.2442] |
| ARCH 5 F( 5, 45) = | 0.31442 | [0.9017] |
| Normality Chi^2(2)= | 0.28122 | [0.8688] |
| Xi^2 F(31, 23) = | 0.47193 | [0.9741] |
| RESET F( 1, 54) = | 1.1028 | [0.2983] |

Here we have transformed two growth rates of the share of government expenditures to nominal GDP (DSALZ) into acceleration rate, DDSALZ. Next, we applied the same transformation to three pairs of variables: DLRER(t-1) and DLRER(t-3), DSTcrS(t) and DSTcrS(t-1), DSTcrS(t-2) and DSTcrS(t-3), to create out of each pair, one variable representing an average growth of the corresponding variable, see Hendry, D. F. (1995, p. 218). This transformation can be represented by the following equation

**Equation 5 Average growth transformation**

$$\frac{1}{2}\alpha\cdot(\Delta x_t+\Delta x_{t-1})=\frac{1}{2}\alpha\cdot(x_t-x_{t-2})=\frac{1}{2}\alpha\cdot\Delta_2 x_t$$

There are two reasons to apply this seemingly cumbersome transformation. First, by combining two variables into one, we gain extra degrees of freedom. Second, the model size gets smaller and becomes easier to interpret. Table 11 presents the final model estimates.

*Table 11 Final model for DLCS estimation results*

**Modelling DLCS by OLS**
**The present sample is: 1993 (6) to 1999 (6)**

| Variable | Coefficient | Std.Error | t-value | t-prob | HCSE | PartR^2 |
|---|---|---|---|---|---|---|
| Constant | -0.0063632 | 0.004597 | -1.384 | 0.1716 | 0.00522 | 0.032 |
| DLCS_2 | 0.19769 | 0.073294 | 2.697 | 0.0091 | 0.10524 | 0.1114 |
| DLCBNFA_1 | 0.29622 | 0.085662 | 3.458 | 0.001 | 0.086971 | 0.1709 |
| DLCBNFA_3 | -0.10383 | 0.05311 | -1.955 | 0.0554 | 0.043737 | 0.0618 |
| DLTT_1 | -0.088189 | 0.045999 | -1.917 | 0.0601 | 0.042423 | 0.0596 |
| DRspLT_3 | -0.0015595 | 0.000529 | -2.95 | 0.0046 | 0.000459 | 0.1305 |
| DvarZ | 0.0056203 | 0.005298 | 1.061 | 0.2932 | 0.003985 | 0.019 |
| ECM_1 | -0.18655 | 0.080037 | -2.331 | 0.0233 | 0.083017 | 0.0856 |
| DDSALZ | -0.038124 | 0.021059 | -1.81 | 0.0754 | 0.017077 | 0.0535 |
| D2DLRER_1 | 0.35883 | 0.12831 | 2.797 | 0.007 | 0.11456 | 0.1188 |
| D2STcrS | 0.0006589 | 0.000238 | 2.771 | 0.0075 | 0.000224 | 0.1169 |
| D2STcrS_2 | -0.00071087 | 0.000267 | -2.666 | 0.0099 | 0.000258 | 0.1092 |
| D93dec | -0.17753 | 0.05159 | -3.441 | 0.0011 | 0.034087 | 0.1696 |
| D95may | 0.30745 | 0.042393 | 7.252 | 0 | 0.022724 | 0.4756 |
| D95dec | -0.19137 | 0.037604 | -5.089 | 0 | 0.018942 | 0.3087 |

R^2 = 0.818691, F(14,58) = 18.707 [0.0000], $\sigma$ = 0.0349143, DW = 2.35
RSS = 0.07070252629 for 15 variables and 73 observations

**Diagnostics test**

| | | |
|---|---|---|
| AR 1- 5 F( 5, 53) = | 1.4546 | [0.2203] |
| ARCH 5 F( 5, 48) = | 0.36752 | [0.8683] |
| Normality Chi^2(2)= | 0.15449 | [0.9257] |
| Xi^2 F(25, 32) = | 0.55519 | [0.9333] |
| RESET F( 1, 57) = | 1.0099 | [0.3192] |

No signs of misspecifications are revealed. All explanatory variables except two (constant and DVarZ – changes in the volatility of government expenditure share) are statistically significant at the 10% level. The error correction coefficient is negative and statistically significant, and shows roughly 20% adjustment per period. Graphic analysis of the final model is presented on Figure 19, Figure 20, and Figure 21. The model fit is good, and, as can be seen from recursive graphics analysis, parameters exhibit a good level of constancy, which can be taken as an indirect validation of our weak exogeneity assumptions. Apart from deterministic variables, error correction term (ECM), and lagged endogenous variable, DLCS depends on seven exogenous explanatory variables. Discussion and analysis of the result is postponed until after forecast tests.

Finally, we check the final model forecast accuracy. We take a year of data, twelve monthly observations, out of sample to be used in this test. The results are presented in Table 12.

*Table 12 Final model for DLCS forecast accuracy*

**Modelling DLCS by OLS**
**The present sample is: 1993 (6) to 1999 (6) less 12 forecasts**
**The forecast period is: 1998 (7) to 1999 (6)**

| Variable | Coefficient | Std.Error | t-value | t-prob | HCSE | PartR^2 |
|---|---|---|---|---|---|---|
| Constant | -0.00511 | 0.005154 | -0.992 | 0.3264 | 0.005652 | 0.0209 |
| DLCS_2 | 0.15674 | 0.075924 | 2.064 | 0.0446 | 0.1067 | 0.0848 |
| DLCBNFA_1 | 0.2846 | 0.097708 | 2.913 | 0.0055 | 0.10488 | 0.1557 |
| DLCBNFA_3 | -0.10875 | 0.054539 | -1.994 | 0.0521 | 0.048466 | 0.0796 |
| DLTT_1 | -0.07248 | 0.051238 | -1.415 | 0.1639 | 0.043344 | 0.0417 |
| DRspLT_3 | -0.00172 | 0.000547 | -3.148 | 0.0029 | 0.000489 | 0.1773 |
| DvarZ | 0.00655 | 0.00551 | 1.189 | 0.2406 | 0.00415 | 0.0298 |
| ECM_1 | -0.16178 | 0.082767 | -1.955 | 0.0567 | 0.087588 | 0.0767 |
| DDSALZ | -0.04869 | 0.022294 | -2.184 | 0.0341 | 0.01869 | 0.0939 |
| D2DLRER_1 | 0.29814 | 0.15139 | 1.969 | 0.055 | 0.13855 | 0.0778 |
| D2STcrS | 0.000651 | 0.000239 | 2.719 | 0.0092 | 0.000249 | 0.1385 |
| D2STcrS_2 | -0.00073 | 0.000271 | -2.684 | 0.0101 | 0.000285 | 0.1354 |
| D93dec | -0.16791 | 0.053472 | -3.14 | 0.0029 | 0.04012 | 0.1765 |
| D95may | 0.31996 | 0.042929 | 7.453 | 0 | 0.022085 | 0.547 |
| D95dec | -0.19373 | 0.037612 | -5.151 | 0 | 0.019649 | 0.3658 |

R^2 = 0.85043, F(14,46) = 18.682 [0.0000], $\sigma$ = 0.0345616, DW = 2.27
RSS = 0.05494729755 for 15 variables and 61 observations

**Analysis of 1-step forecasts**

| Date | Actual | Forecast | Y-Yhat | Forecast SE | t-value |
|---|---|---|---|---|---|
| 1998 7 | -0.00346 | 0.001124 | -0.00458 | 0.035102 | -0.13048 |
| 1998 8 | -0.01971 | -0.00415 | -0.01556 | 0.035542 | -0.43784 |
| 1998 9 | -0.05068 | -0.00078 | -0.0499 | 0.035761 | -1.3953 |
| 1998 10 | 0.004699 | -0.02097 | 0.025668 | 0.039534 | 0.649259 |
| 1998 11 | -0.03812 | -0.01821 | -0.01991 | 0.038364 | -0.51904 |
| 1998 12 | 0.004241 | -0.02283 | 0.027069 | 0.037887 | 0.714463 |
| 1999 1 | -0.01902 | 0.025826 | -0.04485 | 0.037361 | -1.20046 |
| 1999 2 | 0.082997 | -0.00014 | 0.083133 | 0.036065 | 2.30507 |
| 1999 3 | -0.08904 | -0.04698 | -0.04206 | 0.036972 | -1.13753 |
| 1999 4 | -0.01898 | -0.00157 | -0.01742 | 0.03707 | -0.46982 |
| 1999 5 | -0.03506 | 0.005993 | -0.04105 | 0.036921 | -1.11193 |
| 1999 6 | 0.04274 | 0.039848 | 0.002892 | 0.038209 | 0.075702 |

**Tests of parameter constancy over: 1998 (7) to 1999 (6)**
Forecast Chi^2(12)= 14.424 [0.2745]
Chow F(12, 46) = 1.0991 [0.3836]

**Diagnostics tests**

| | | |
|---|---|---|
| AR 1- 5 F( 5, 41) = | 1.5982 | [0.1822] |
| ARCH 5 F( 5, 36) = | 0.80552 | [0.5533] |
| Normality Chi^2(2)= | 2.6739 | [0.2626] |
| Xi^2 F(25, 20) = | 0.53429 | [0.9308] |
| RESET F( 1, 45) = | 0.60557 | [0.4405] |

The parameters are constant over the forecast period. The average forecast standard error is 3.71% and never exceeds 3.95%. The result of forecasting can be seen in Figure 22. 3- and 12-step ahead dynamic (ex-ante) forecasts do not differ noticeably, and are presented on Figure 23. The only point of interest here is to compare this model forecast accuracy with that of our univariate model. The comparison is favourable for the model with explanatory variables, average standard forecast error falls from 4.38% for univariate model to only 3.71% for the model with explanatory variables – nearly 15 % better. The gain in accuracy is small, bit not negligible. However, the goal of multivariate modelling with explanatory variables is rather to uncover some structural relationship among economic variables of interest than to get superior forecasts.

Continuing to explore the dynamic structure of the final model, we present lag structure analysis in Table 13. All lags were found to be highly significant.

*Table 13 Final model lag structure analysis*

| Lag | 0 | 1 | 2 | 3 | Sum |
|---|---|---|---|---|---|
| **DLCS** | -1 | 0 | 0.198 | 0 | -0.802 |
| StdErr | 0 | 0 | 0.0733 | 0 | 0.0733 |
| **Constant** | -0.00636 | 0 | 0 | 0 | -0.00636 |
| StdErr | 0.0046 | 0 | 0 | 0 | 0.0046 |
| **DLCBNFA** | 0 | 0.296 | 0 | -0.104 | 0.192 |
| StdErr | 0 | 0.0857 | 0 | 0.0531 | 0.102 |
| **DLTT** | 0 | -0.0882 | 0 | 0 | -0.0882 |
| StdErr | 0 | 0.046 | 0 | 0 | 0.046 |
| **DRspLT** | 0 | 0 | 0 | -0.00156 | -0.00156 |
| StdErr | 0 | 0 | 0 | 0.000529 | 0.000529 |
| **DvarZ** | 0.00562 | 0 | 0 | 0 | 0.00562 |
| StdErr | 0.0053 | 0 | 0 | 0 | 0.0053 |
| **DDSALZ** | -0.0381 | 0 | 0 | 0 | -0.0381 |
| StdErr | 0.0211 | 0 | 0 | 0 | 0.0211 |
| **D2STcrS** | 0.000659 | 0 | -0.000711 | 0 | -5.20E-05 |
| StdErr | 0.000238 | 0 | 0.000267 | 0 | 0.000391 |
| **D2DLRER** | 0 | 0.359 | 0 | 0 | 0.359 |
| StdErr | 0 | 0.128 | 0 | 0 | 0.128 |
| **ECM** | 0 | -0.187 | 0 | 0 | -0.187 |
| StdErr | 0 | 0.08 | 0 | 0 | 0.08 |
| **D93dec** | -0.178 | 0 | 0 | 0 | -0.178 |
| StdErr | 0.0516 | 0 | 0 | 0 | 0.0516 |
| **D95may** | 0.307 | 0 | 0 | 0 | 0.307 |
| StdErr | 0.0424 | 0 | 0 | 0 | 0.0424 |
| **D95dec** | -0.191 | 0 | 0 | 0 | -0.191 |
| StdErr | 0.0376 | 0 | 0 | 0 | 0.0376 |
| **Mean Lag = -0.4** | | | | | |

As can be seen, average changes in spread on short term credits (D2STcrS) do not affect the long-run rate of CS growth (DLCS). Then (leaving aside constant term, dummies, and error-correction term) the long-run rate of CS growth (DLCS) depends on six exogenous variables only. It responds positively to an increase in the growth rate of central bank net foreign assets (DLCBNFA), as found in Rogers, J. H. (1996)[23]; an average growth of the real effective exchange rate depreciation (D2DLRER) as in Mongardini, J. and J. Mueller (1999, p.18, Table 3); and the growth of volatility of government expenditures share in GDP (DVarZ). This variable (DVarZ) was left in the regression, despite its not very high t-statistics, to show that even with such poor quality data on transition in Latvia the effect of changes in volatility on CS can be identified. We would argue, that in the better quality data samples it should be possible to identify the effects of volatilities of inflation and exchange rate on other economic variables. It responds negatively to an increase in the growth rate of total trade share in GDP (DLTT), which is unexpected; the growth rate of real spread on long term deposits (DRspLT), as found in Boero, G. and G. Tullio (1996)[24], and in Mongardini, J. and J. Mueller (1999, p.18, Table 3); and the acceleration rate of government expenditures share in GDP (DDSALZ). Spread can be thought about as the opportunity cost of currency substitution for household, hense, when it is rising CS is falling.

Also from lag structure analysis it can be seen that DLCS responds immediately to changes in DDSALZ, DVarZ, and D2STcrS, with one lag to changes in DLCBNFA, DLTT, and D2DLRER, with two lags to changes in itself and D2STcrS again, and with three lags to changes in DrspLT and DLCBNFA again. As noticed above effects of average changes in spread on short term credits (D2STcrS) cancel each other and this variable does not affect the long run behaviour of CS. Model unit impulse response is presented on Figure 24.

[23] See, for example, his Table 7.5a on p.125, variable DFR. We assume here, rather bravely, that what affects domestic money holdings negatively is positive for the CS level. This is a necessary assumption to make any comparison possible, because, as mentioned before, most empirical research deals with domestic money demand rather than with CS itself.
[24] See their Table 9A.3 on p.176, variable dRL.

# 6 Conclusion

Consistent methodology and theoretical insights from Sarajevs, V. (1999) on the role of uncertainty have helped create a well-behaved econometric model for currency substitution, that, in particular, takes into account the role of volatilities in the behaviour of this complex phenomenon. Direct modelling of the CS ratio was used, instead of the predominant tradition of indirect modelling, where the degree of currency substitution is inferred from the dependence of domestic money demand on foreign variables.

Some variable signs in long-run and short-run dynamics of the CS remain a puzzle. Therefore, we must refrain from policy recommendations at this early stage of research. From Table , we see a set of variables over which the government (fiscal and monetary authorities together) seems to have some degree of control. These are (in order of controllability)

- the growth rate of central bank net foreign assets (DLCBNFA),
- spreads on credits and deposits, and
- the acceleration rate of government expenditures and its variability.

Of course, only net foreign assets and spreads can be continuously affected by central bank policies.

Another reason to postpone a prescription of clear policy receipts is that the whole issue of currency substitution being good or bad for the economy has not been resolved yet, neither theoretically nor empirically. Therefor, the balance of related hidden costs and benefits[25] can not be assessed correctly.

Although a little light was shed on this problem of extreme complexity, much more empirical research on other countries' experience with the CS phenomenon is necessary to construct a reliable set of evidence on signs and relative significance of different variables for the CS process. This may help to tackle traditional problems of empirical research of transition economies (poor quality data and small sample size), and will greatly

[25] See the last three paragraphs of the second section for a short list of costs and benefits associated with the presence of currency substitution.

facilitate further theoretical investigation of the currency substitution phenomenon.

Nevertheless, the research confirms the importance of such established factors as spread, the rate of depreciation of the exchange rate, and foreign reserves in CS determination. They further highlight relatively unknown factors such as shares of total trade and government expenditures in GDP and volatility of government expenditures. These factors should be considered by policymakers wishing to assess or affect the behaviour of the CS ratio.

# Appendices

## Appendix A. Timeline of major political and economic events in Latvia in 1991-1999

**1991**

*January*: A new tax system is introduced. The First Tax Reform package seeks to improve revenue collection and stimulate private savings. The system includes a profit tax, personal income tax, land tax, a natural resource tax, an excise tax, a social tax and custom duties. Eventually, the system proves to be inefficient, complicated, riddled with exemptions and discouraging for new entrepreneurs. Between 1993 and 1996, a Second Tax Reform will be gradually introduced, mainly eliminating numerous tax exemptions and introducing uniform tax rates.

*March 3*: In a referendum, 73.7% of voters choose independence.

*September*: Latvia gains international recognition as an independent state. Economic reforms start immediately.

*November-December*: Two government decisions initiate price liberalisation, causing a two-fold increase in prices of meat, bread and dairy products, and five- to six-fold increases in prices of gas, electricity, heating and hot water.

**1992**

In mid-1992, a stabilisation and reform programme is adopted.

*May 7*: The Latvian rouble is introduced into co-circulation at par with the Soviet rouble as a first step in gaining monetary independence.

*May 19*: The Law on the Bank of Latvia is approved, establishing the central bank as an independent monetary authority. Next, the Foreign Exchange department of the Bank of Latvia was founded. In mid-1992, Latvia also regains ownership of its pre-war (1940) gold reserves held with the Bank of England.

*July*: The Bank of Latvia was set up in July 1990 as the Central Bank of the republic.

*July 20:* The Latvian Rouble is declared the only legal tender in Latvia. Its exchange rate against the Russian Rouble is freely determined in the foreign exchange market. All bank deposits are exchanged on a one-to-one basis.

*December*: There are 15.5 billion Latvian Roubles in circulation.

**1993**

By the beginning of 1993 the first positive results of the reforms are felt. After the initial jump, inflation falls to single-digit monthly figures. However, structural reforms are still in their infancy.

**Average Annual Inflation**

| Date | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 |
|---|---|---|---|---|---|---|---|---|---|
| ΔCPI,% | 11 | 125 | 951 | 109 | 36 | 25 | 18 | 7 | 3 |

*March 5:* Gradual introduction of a national currency, the lat, begins.

*June 6-7*: The first parliamentary elections are held.

*October 18*: The lat becomes the sole legal tender in Latvia. Full monetary independence is established.

*December*: The first Treasury Bills (T-bills) are issued.

By the end of the year, domestic public confidence in national money increased significantly. This was largely due to a firm anti-inflationary stance by the Bank of Latvia, after conducting independent monetary policy since the middle of 1992. The main goal of monetary policy in 1993 was price stability.

**1994**

*January-March*: The Bank of Latvia becomes a net seller of foreign currency, mainly in response to a rise in expectations of a lat depreciation and a decline in the real interest rates for lat deposits.

*February*: The Bank of Latvia unofficially pegs the lat to the SDR (1 LVL = 0.7997 SDR), and the priority in monetary policy is given to exchange rate stability. The Latvian Privatization Agency is also created to promote and speed up the privatisation process.

*August 31:* The last Soviet troops pull out of Latvia.

**1995**

While by no means a black year for the Latvian economy, the anticipated growth in GDP abruptly reversed into decline after the first banking crisis in post-Soviet Latvia. As of end-1994, there were 67 commercial banks in operation. Lack of experience, bad loans, excessive risk taking and speculations, fraud on the side of commercial banks and lack of supervision on the side of the Bank of Latvia led to a debacle.

*May-June*: The largest commercial bank in Latvia, *Banka Baltija*, which holds 30% of total deposits, fails. *Banka Baltija* is declared insolvent on *June 27*. Three other banks, which together with *Banka Baltija* hold 46% of deposits from private persons and comprise 30% of total assets of the banking system, also collapse. This leads to a run on other banks. By the end of the year, only 38 commercial banks still operate; 29 are lost in the crisis. By June 1996, only 36 banks remain, and only 12 are any longer allowed by the Bank of Latvia to accept household deposits.

The consequences of the banking crisis are a fall in real GDP, a decline in broad money (M2X) of 35% in real terms, a 45% fall in domestic bank credits in real terms, and sharply higher interest rates. Public confidence in domestic banking system is seriously undermined, with the public preferring to hold foreign currency rather than deposits.

**Real Gross Domestic Product, percentage change**

| Date | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 |
|---|---|---|---|---|---|---|---|---|
| GDP | -8.3 | -32.9 | -17.5 | 0.6 | -0.8 | 3.3 | 8.6 | 3.6 |

*July*: The Riga Stock Exchange is established. First trading is held on July 25. The exchange's start is sluggish, so that by 1996 its capitalisation is only 1% of GDP, or 40 millions lats.

*October 1*: The second parliamentary elections take place with inconclusive results. None of the nine parties in parliament receive more than 18 out of 100 seats.

*November-December*: Political uncertainty continues as political parties fail to form a new government.

**1996**

*January*: The parliament still fails to approve its long-overdue state budget for 1996.

*January-March*: Interest rates begin to fall as the effects of the banking crisis fade. Public confidence in the domestic financial system returns.

*April*: On the T-bill market, positive development is marked by the introduction of a one-year bill. By September 1996 these account for about 25% of outstanding bills.

*October*: By cutting the refinancing rate frequently during a year, the Bank of Latvia lowers from 25% in November 1995 to 10% in October 1996.

**1997**

A number of positive events occur in the financial markets. The consequences of the late-May 1995 banking crisis are overcome, and the number of core banks, which are allowed to accept deposits, grows from 12 to 19 by December 1997 with total number of banks equal 33. The top four banks perform about 80% of lending activities and hold some 70% of deposits.

The equity market expanded rapidly during 1997 with market capitalisation on the Riga Stock Exchange increasing from 2.7% of GDP in January 1997 to 6.3% of GDP in December 1997.

*October-December*: The Asian economic crisis brings extra turbulence to already highly volatile financial markets in the FSU and Baltic republics, alerting foreign investors to withdraw or suspend investments on emerging markets.

**1998**

*March*: A new mortgage lending law is passed. Loans are of one-year maturity, can be rolled over for ten years and can amount to 60% of the value of the underlying real estate.

*Mid-1998*: The privatisation of small and medium-scale enterprises is completed. Several large-scale enterprises remain to be privatised, including the Latvian Shipping Company (LASCO), Latvenergo, Lattelekom and Air Baltic.

*October-December*: The Russian economic crisis of August hits the Latvian economy with real GDP contracting 1.9%. A number of commercial banks are badly affected by the Russian default on its sovereign obligations (government bonds).

*October 1*: The deposit insurance scheme comes into effect covering bank deposits up to 500 lats per depositor per bank.

*October 3*: Third parliamentary elections take place.

## 1999

*February*: Latvia joins the World Trade Organisation (WTO) gaining favourable trade conditions with well over a hundred countries.

*March*: The operation of *Rigas Kommerc Banka* (RKB), the oldest and fifth largest commercial bank, is suspended in the midst of a run. RKB's troubles were a consequence of the Russian crisis and problems with Russian government bonds.

Market capitalisation continues to grow on the Riga Stock Exchange, and reaches 13.9% of GDP in March 1999.

*May*: The official unemployment rate reaches 10.1%, more than 3% higher than a year before.

*May 14*: The Bank of Latvia approves a rehabilitation plan for the RKB with total commitment by the Bank of Latvia amounting to nearly 1% of GDP.

Consolidation of the banking sector continues. Presently 24 banks operate, compared with 32 at the end of 1997 and 27 at the end of 1998.

*November 13*: Referendum held on pension increase. The outcome is favourable to the government, which objected to any increase in pensions.

# Appendix B. Graphics

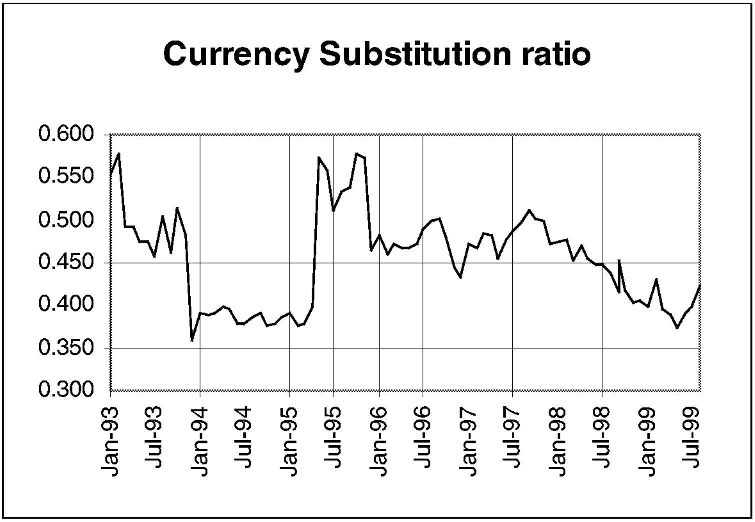


*Figure 1 Currency Substitution ratio*

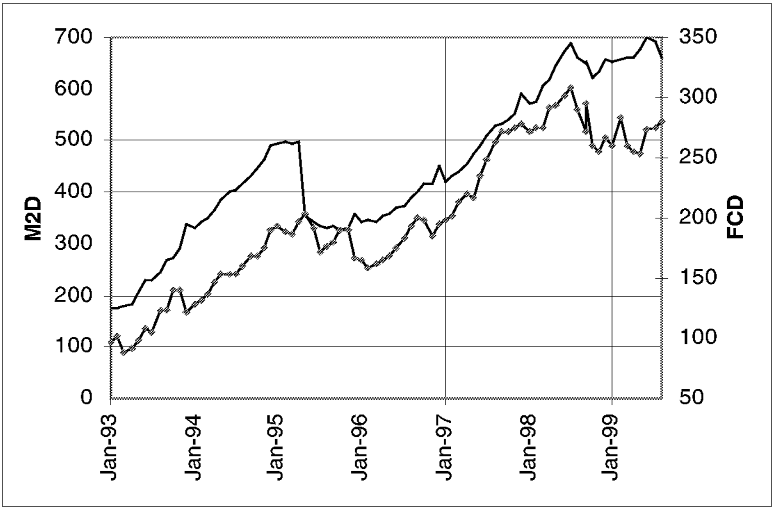


*Figure 2 Components of CS ratio (M2D - clear line)*

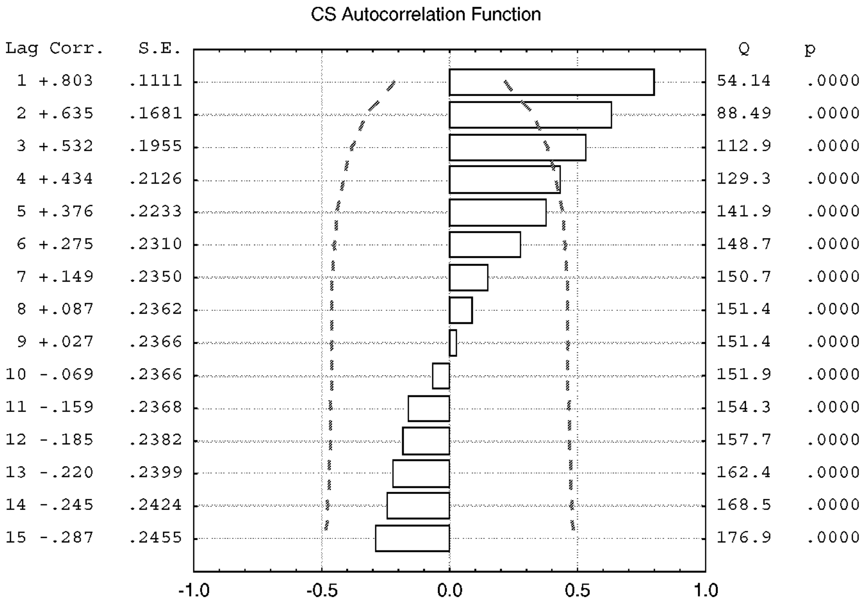


*Figure 3 CS ratio Autocorrelation Function*

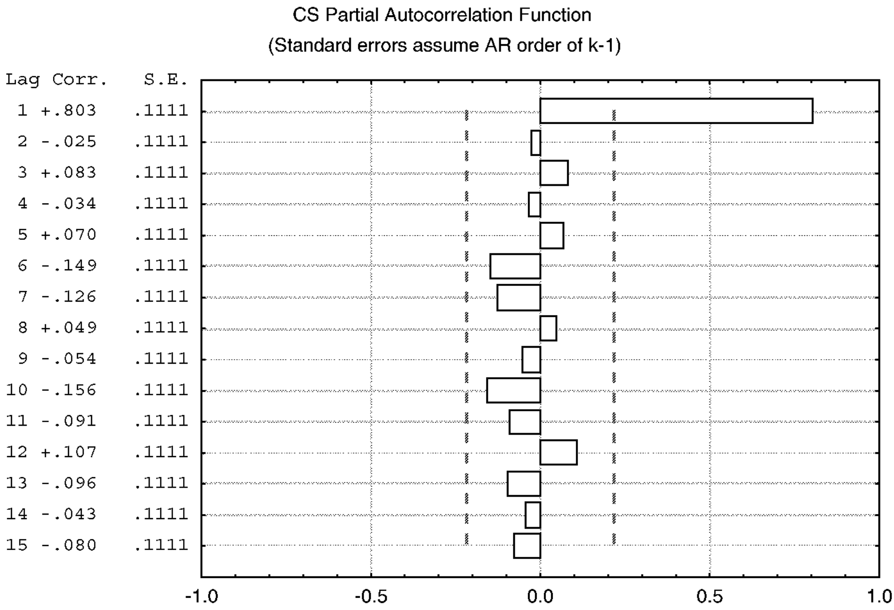


*Figure 4 CS ratio Partial Autocorrelation Function*

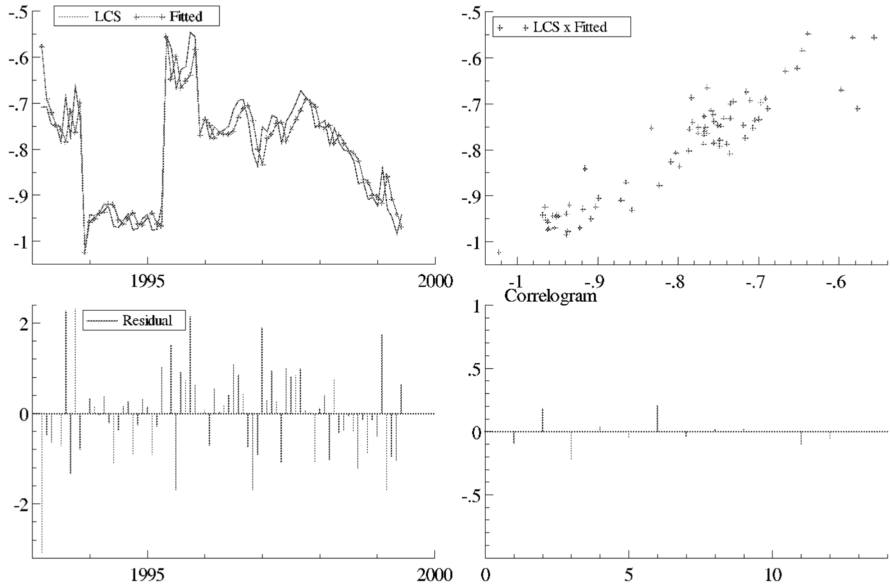


*Figure 5 Graphic analysis of a univariate AR(2) model for CS ratio*

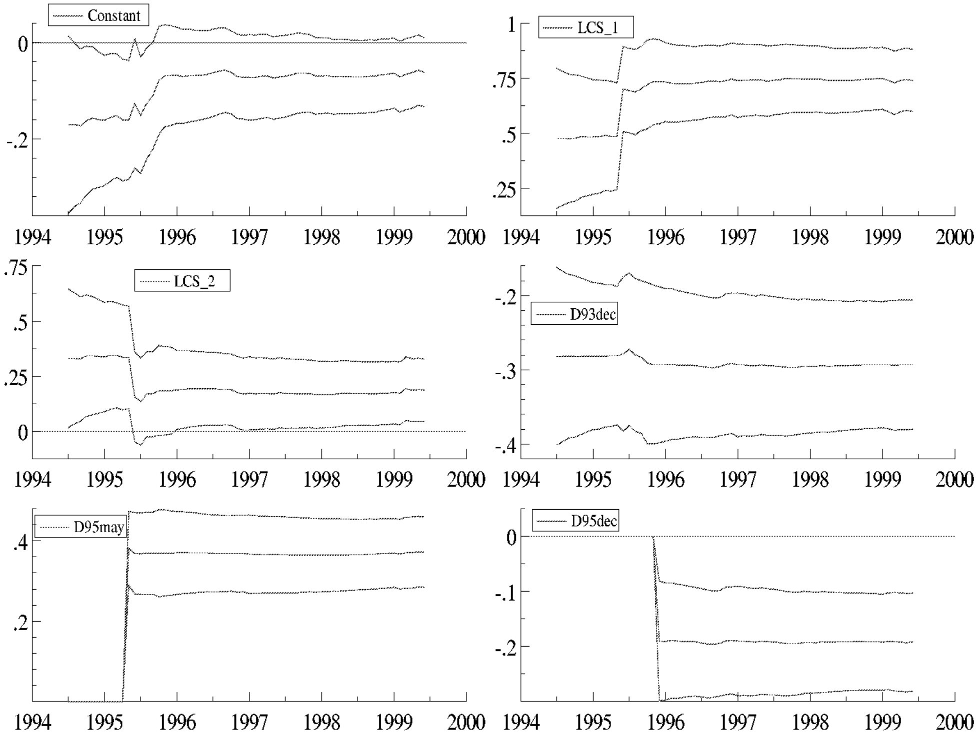


*Figure 6 Recursive graphic analysis: parameters constancy*

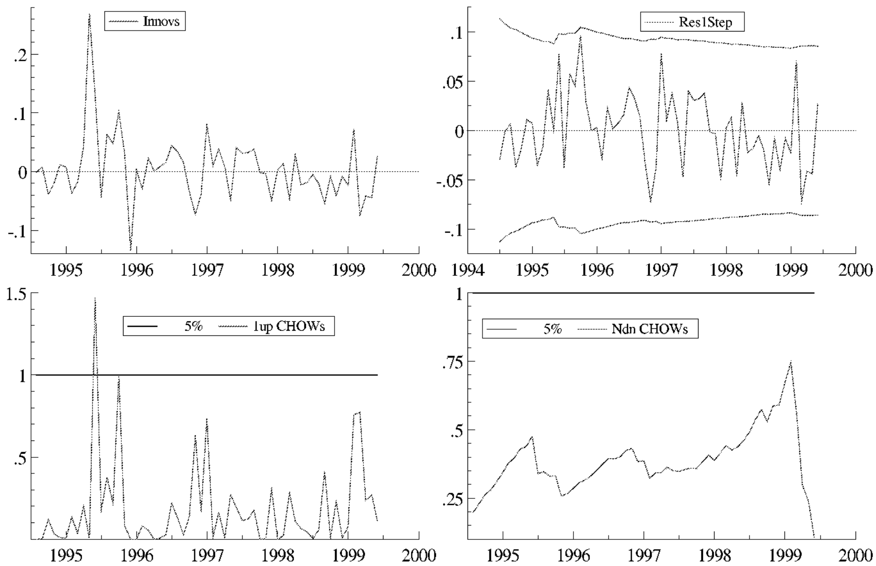


*Figure 7 Recursive graphic analysis*

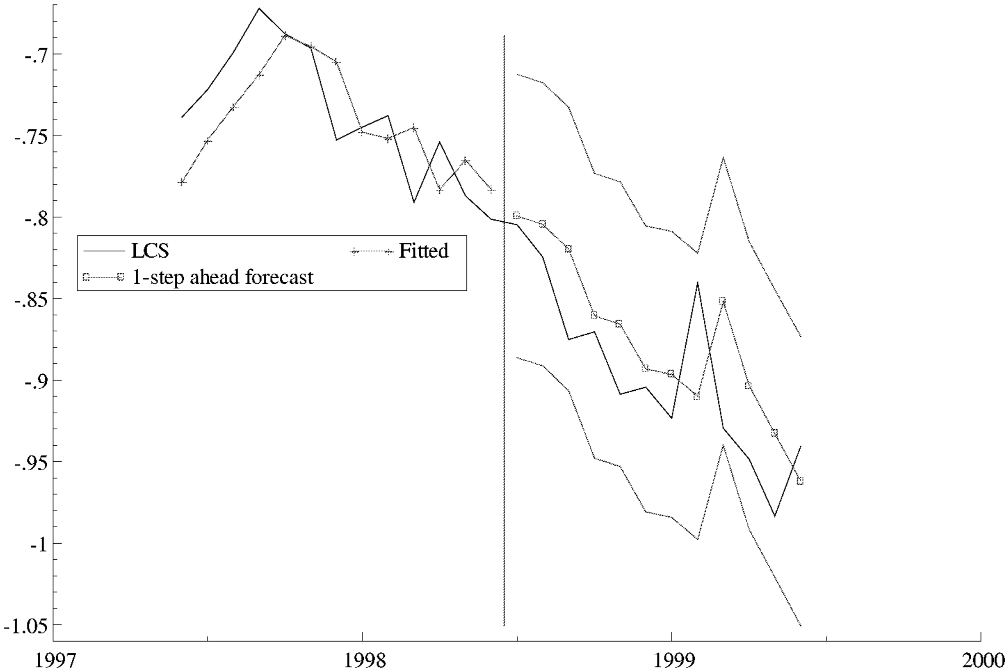


*Figure 8 1-step ahead forecasts for AR(2) model of CS*

Residuals Autocorrelation Function
(Standard errors are white-noise estimates)

| Lag | Corr. | S.E. | Q | p |
|---|---|---|---|---|
| 1 | -.086 | .1125 | .58 | .4468 |
| 2 | +.168 | .1117 | 2.85 | .2411 |
| 3 | -.195 | .1110 | 5.95 | .1143 |
| 4 | +.036 | .1102 | 6.05 | .1951 |
| 5 | -.034 | .1094 | 6.15 | .2920 |
| 6 | +.167 | .1087 | 8.52 | .2024 |
| 7 | -.029 | .1079 | 8.59 | .2831 |
| 8 | +.014 | .1071 | 8.61 | .3762 |
| 9 | +.013 | .1063 | 8.63 | .4725 |
| 10 | +.012 | .1055 | 8.64 | .5667 |
| 11 | -.069 | .1047 | 9.08 | .6150 |
| 12 | -.037 | .1039 | 9.20 | .6854 |
| 13 | +.003 | .1031 | 9.20 | .7573 |
| 14 | -.084 | .1023 | 9.88 | .7708 |
| 15 | +.123 | .1014 | 11.36 | .7270 |

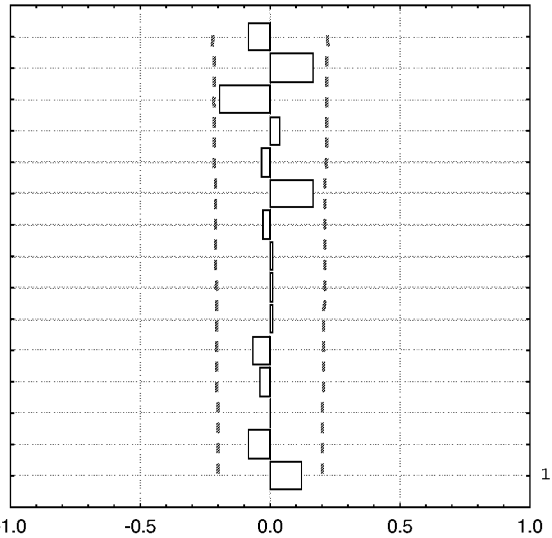


*Figure 9 Residuals Autocorrelation Function from AR(2) model for CS*

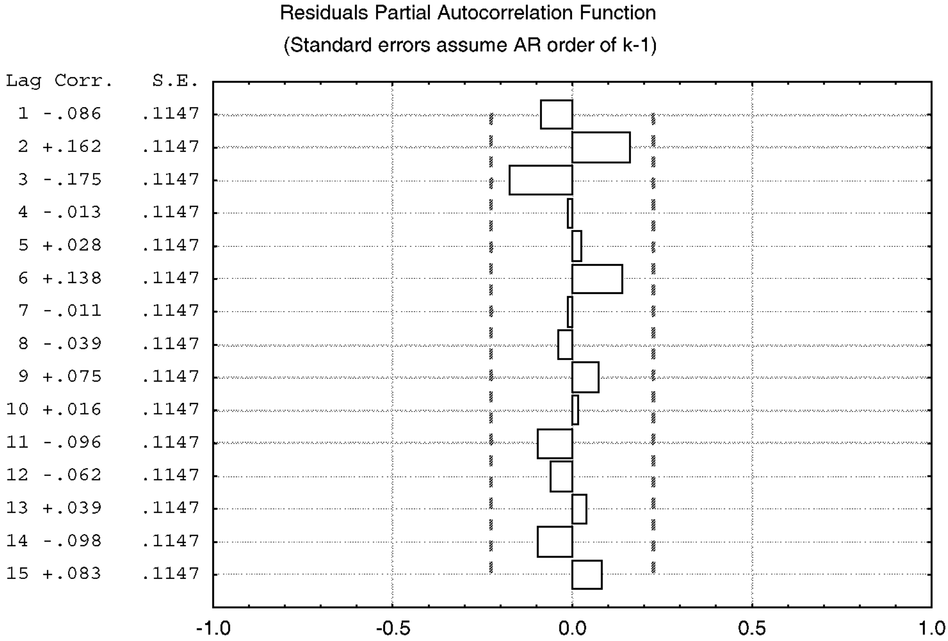


*Figure 10 Residuals Partial Autocorrelation Function from AR(2) model for CS*

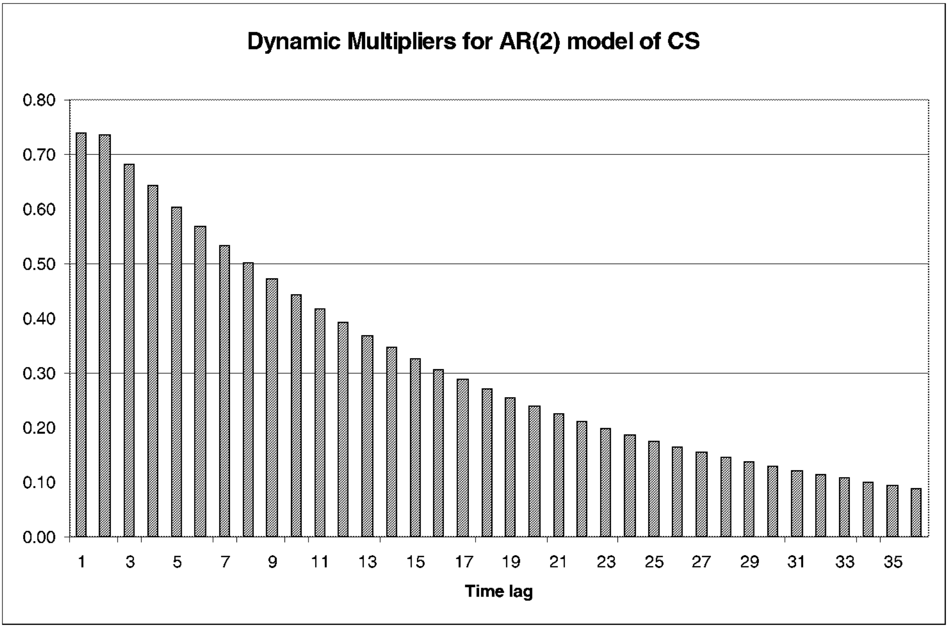


*Figure 11 Dynamic Multipliers for AR(2) model of CS*

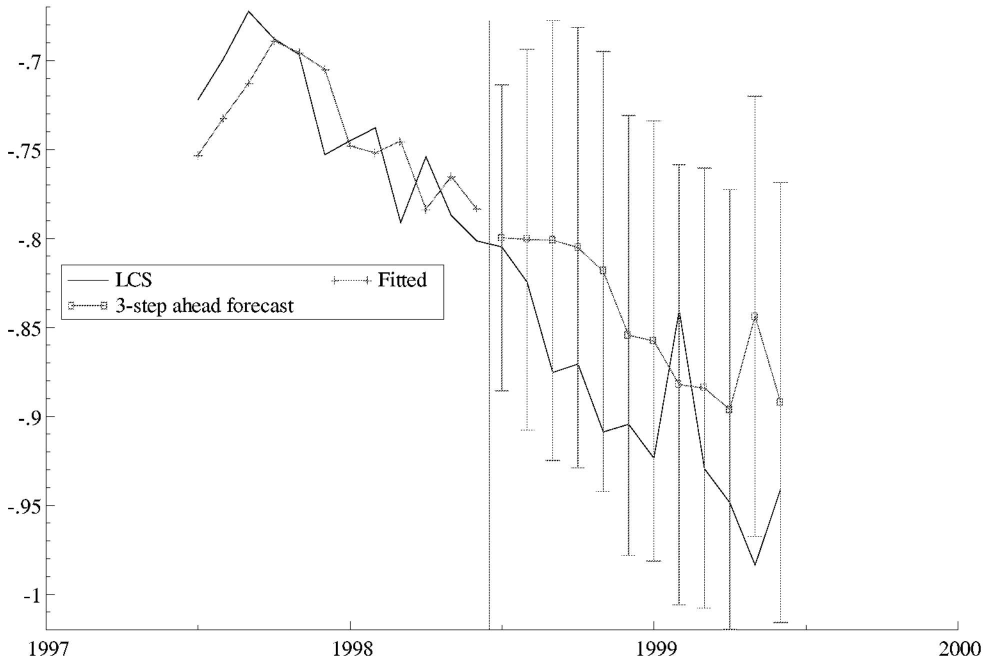


*Figure 12 3-step ahead forecasts for AR(2) model of CS*

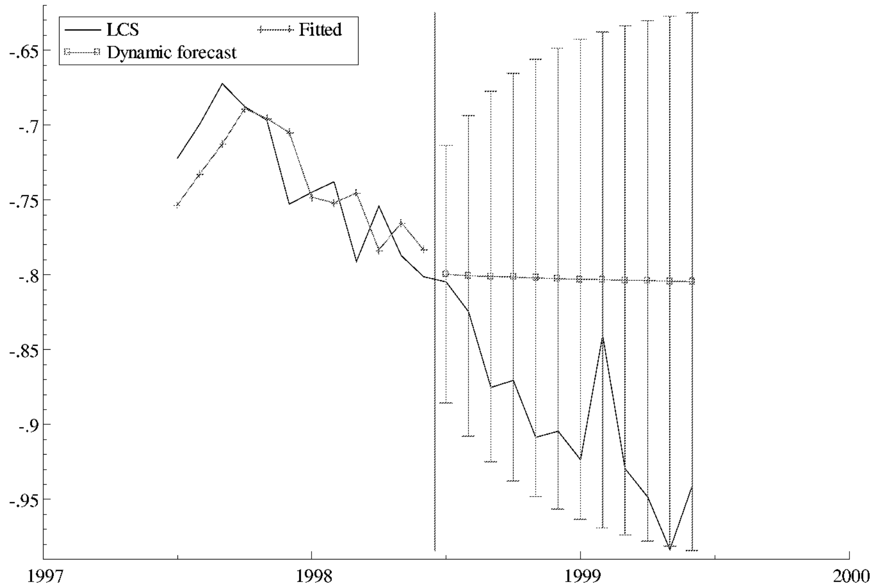


*Figure 13 Dynamic forecasts for AR(2) model of CS*

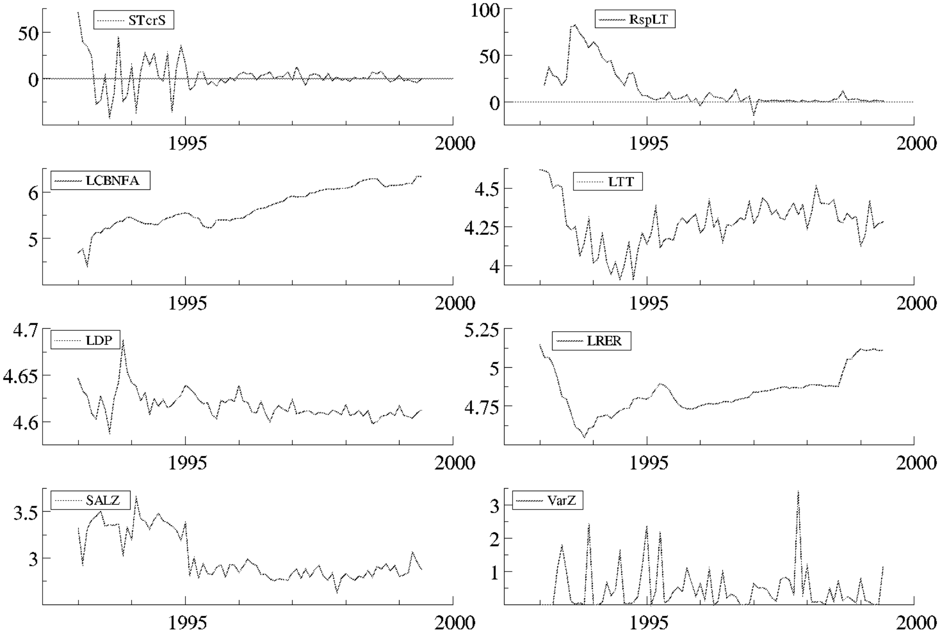


*Figure 14 Explanatory variables – actual values*

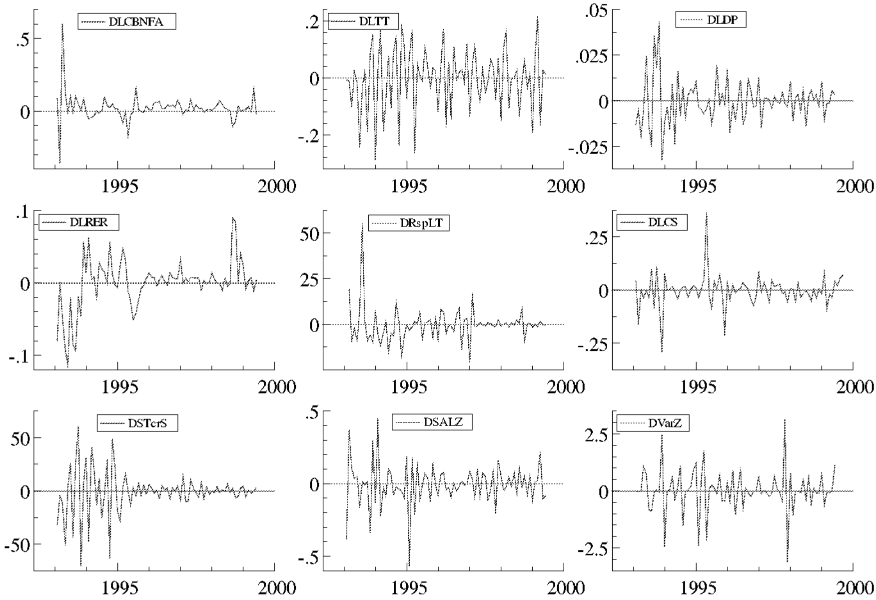


*Figure 15 Explanatory variables and CS – first differences*

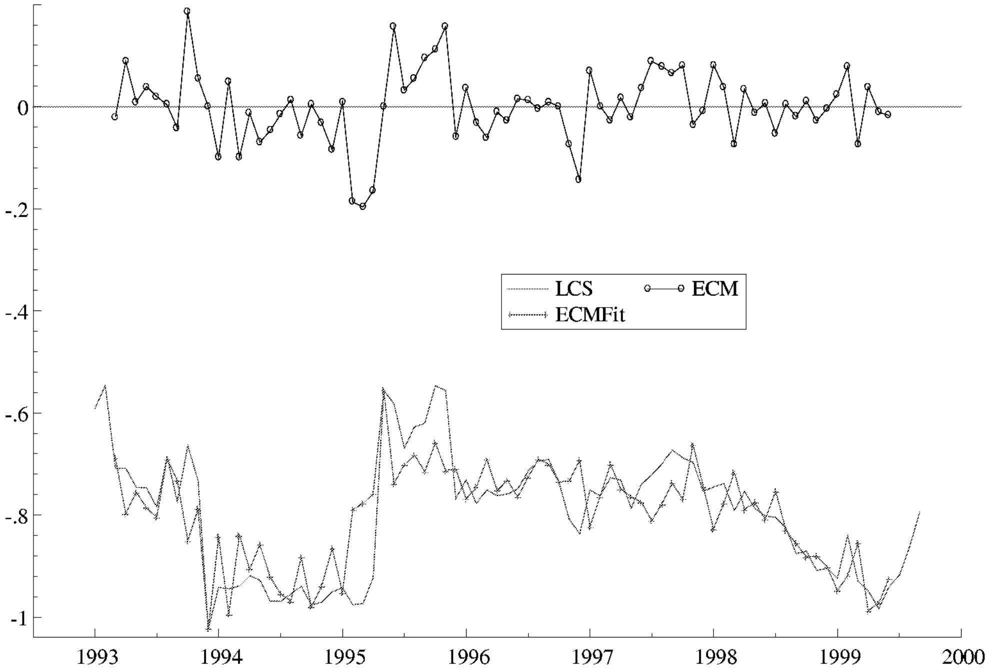


*Figure 16 Error correction vector (ECM) and model fit. Case with dummies as in Table*

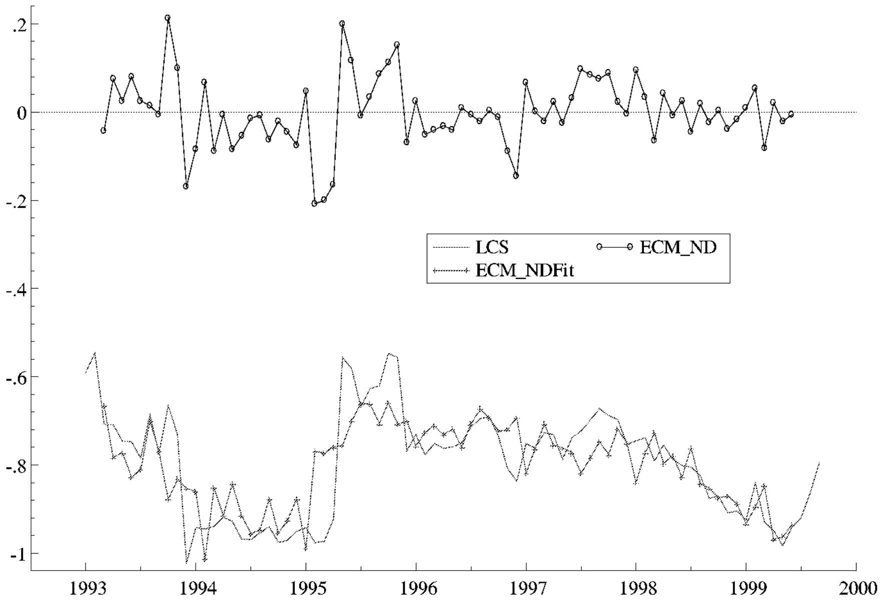


*Figure 17 Error correction vector (ECM_ND) and model fit. Case with no dummies*

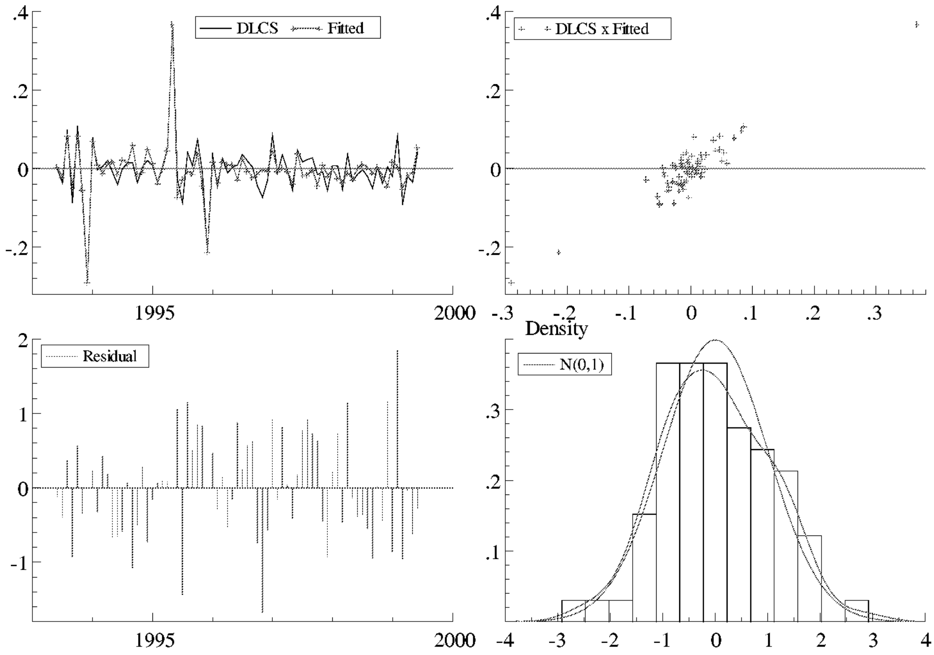


*Figure 18 ADL(4;4) model for CS in ECM form*

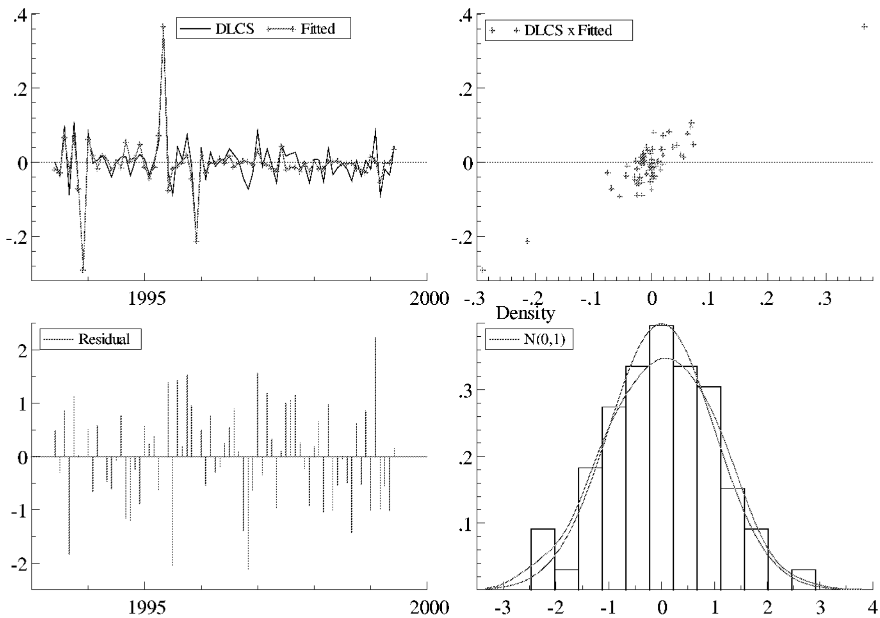


*Figure 19 Final model for DLCS fit and residual analysis*

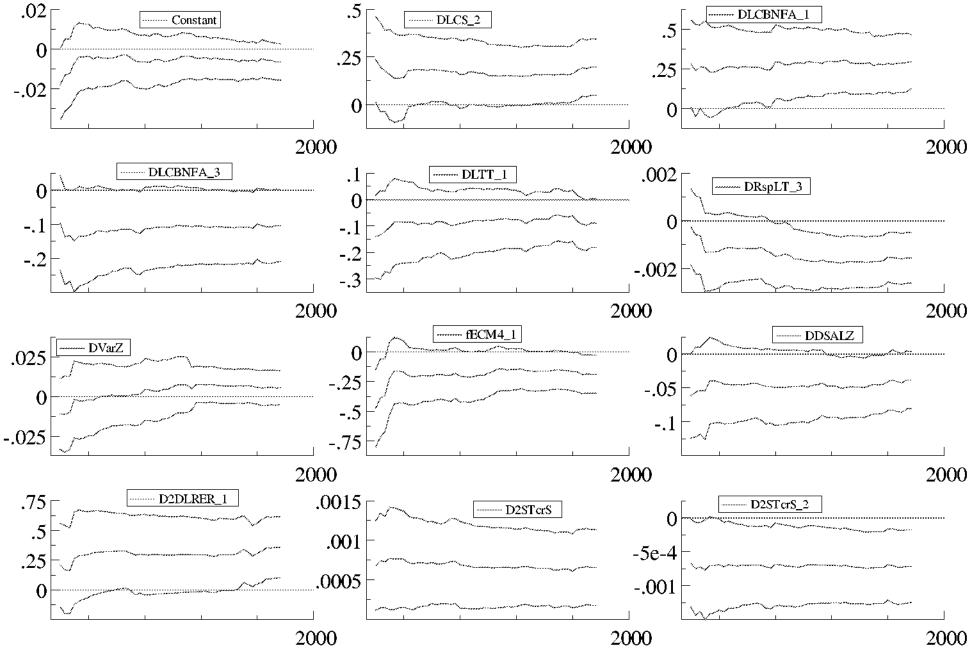


*Figure 20 Recursive graphics – final model parameters constancy*

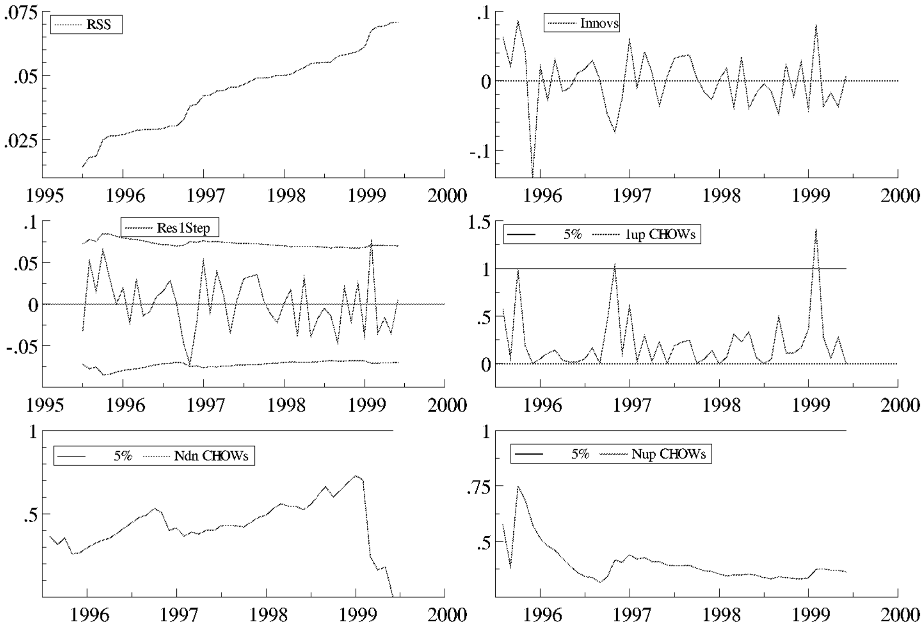


*Figure 21 Recursive graphics – final model innovations and constancy analysis*

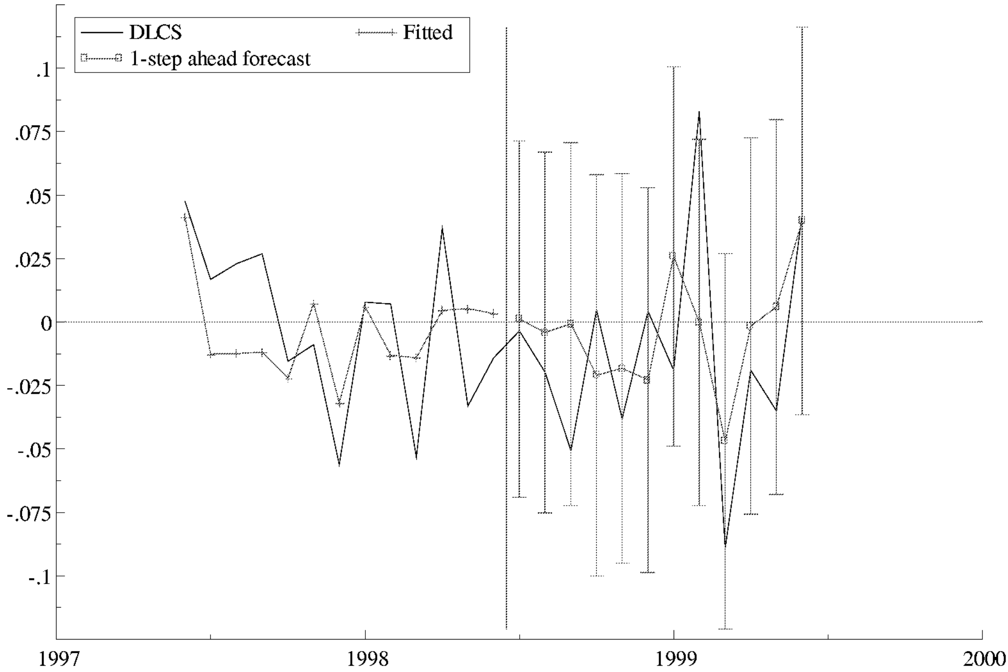


*Figure 22 Final model 1-step ahead (static, ex-post) forecast for DLCS*

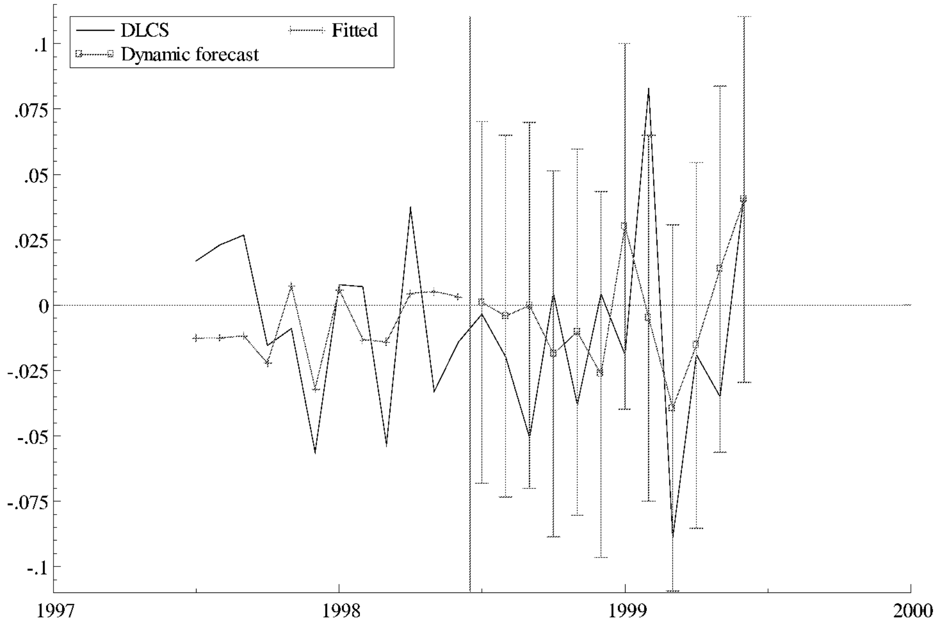


*Figure 23 Final model dynamic (ex-ante) forecast for DLCS*

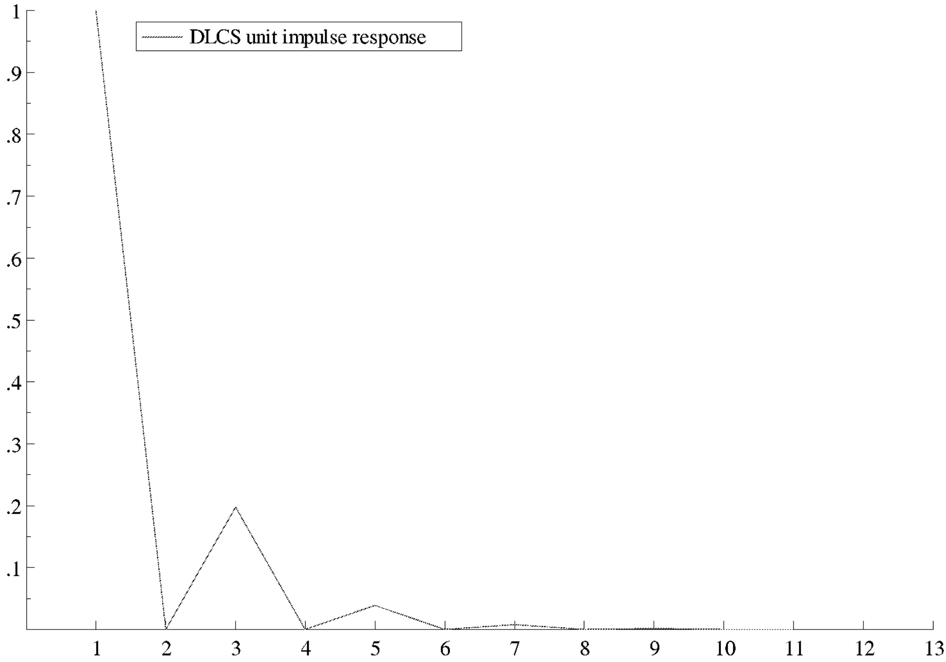


*Figure 24 Final model for DLCS Unit Impulse Response*

## Appendix C. Econometric tests

The following notations and definitions are used. They are found in the Help section of PcGive 9.10 by Hendry, D. F. and J. A. Doornik (1996).

The following diagnostic tests are performed.

| **The null hypothesis** | **vs** | **the alternative** |
|---|---|---|
| white noise | vs | residual serial correlation |
| constant variance | vs | residual ARCH |
| normality | vs | residual non-normality |
| homoscedasticity | vs | residual heteroscedasticity |
| linearity | vs | functional form mis-specification |

**Error autocorrelation (AR)** yields a Lagrange-Multiplier (LM) test for serial correlation, F-test statistics is shown. The null hypothesis is rejected if the test statistic is too high.

**Autoregressive Conditional Heteroscedasticity (ARCH)** checks whether the residuals have an ARCH structure, F-test statistics are shown. The null hypothesis is rejected if the test statistic is too high.

**Normality** calculates a normality test on the residuals, and checks whether the variables (residuals in this case) are normally distributed. A $Chi^2$ test is reported. The null hypothesis is normality, which will be rejected at the 5% level if a test statistic of more than 5.99 is observed.

**Functional form misspecification (Xi^2 and Xi*Xj)** checks if linearity is reasonable against $u^2$ (squared residuals) depending on squares and cross-products of the regressors. The null hypothesis is no functional form mis-specification, which would be rejected if the test statistic is too high. This test is done by regressing the squared residuals on a constant, the original regressors, the original regressors squared and all the cross-products. An F-test is reported.

**The RESET test (Regression Specification Test)** checks if y depends on $y^n$, $n = 2,\ldots,4$, thus testing for functional form misspecification. The null hypothesis is no functional form misspecification, which would be rejected if the test statistic is too high.

**JHCSE** stands for jackknife heteroscedastic consistent standard error. These provide consistent estimates of the regression coefficients' standard errors, even if the residuals are heteroscedastic in an unknown way.

**Durbin-Watson Test (DW).** This is a test for autocorrelated residuals. DW is most powerful as a test of white noise against a first-order autoregressive error. DW is a valid statistic only if all the regressor variables are at least strongly exogenous. If the model includes a lagged dependent variable, then DW is biased towards 2, i.e. against detecting autocorrelation.

**Residual standard deviation (sigma, σ).** This is the standard deviation of the difference between the actual and fitted values in the regression. For a given dependent variable, sigma can be standardised as a percentage of the mean of the original level of the dependent variable y (except when the mean is zero) for comparisons across specifications. Since many economics magnitudes are inherently positive, standardisation is often feasible. If variable is in logs, 100 times sigma is the percentage standard error.

**Dickey-Fuller test.** The augmented Dickey-Fuller (ADF) test provides a useful description of the degree of integratedness of x. It is provided by the t-statistic on the coefficient δ at lagged x in:

$$\Delta x_t = \alpha + \gamma t + \delta x_{t-1} + \beta_1 \Delta x_{t-1} + \ldots + \beta_s \Delta x_{t-s} + \varepsilon_t$$

One can choose whether to include a constant or constant+trend, and the lag length s. The Dickey-Fuller test arises with s=0. The null hypothesis is that of a unit root. This is rejected if the t-statistic is negative and significantly different from zero. Note that the t-statistic on the coefficient δ at lagged x does not have the conventional t-distribution. PcGive can produce a table of ADF tests, dropping one lag at a time.

Reported are:

| | |
|---|---|
| t-adf: | ADF t-statistic (/ se()); |
| beta y_1: | one plus coefficient on lagged level (+1); |
| sigma: | equation standard error; |
| lag: | highest lag used (value of s); |
| t-Dy_lag: | t-value on last ß (which is the coefficient on last x); |

t-prob: significance level of t-DY_last, which is t-distributed.

F-prob: significance level of the F-test on the lags dropped up to that point.

AIC: Akaike information criterion.

**Recursive estimations** provides the following graphical output:

1. Beta coefficient ± 2SE; the graph is centred on ß with the approximate 95% confidence interval at each observation shown on either side.

2. Residual Sums of Squares; this graphs RSS at each t, based on the OLS residuals:

$$RSS_t = \sum_{s=1}^{t} v_s^2, where\, v_s = y_s - x_s' \cdot \beta_t .$$

3. Standardised innovations defined by:

$$e_t = \left(y_t - x_t' \cdot \beta_{t-1}\right) / f_t, where f_t = \sqrt{1 + x_t'\left(X_{t-1}' X_{t-1}\right)^{-1} x} .$$

4. 1-step residuals with 0 ± 2σ, showing u = y - x'β and twice the equation standard error at each t on either side of zero. This will reveal any model deficiencies.

5. 1-step Chow tests scaled by their critical values at the 5% level (or a user defined probability level, with 0% leading to unscaled chows) at each t, so that the 5% value is a straight line independent of t and the changing degrees of freedom. It does not allow for the number of tests conducted.

6. N decreasing Chow tests (again scaled by their critical values), so that the value shown at t tests for constancy from t to T.

7. N increasing Chow tests (again scaled by their critical values), so that the value shown at t tests for constancy from m+1 to t.

# References

Agenor, P. R. and M. S. Khan (1996) "Foreign currency deposits and the demand for money in developing countries," Journal of Development Economics 50(1): 101–118.

Arrau, P., J De Gregorio, C. Reinhart, and P. Wickham (1991) "The Demand for Money in Developing Countries: Assessing the Role of Financial Innovation," International Monetary Fund Working Paper, *IMF Working Papers* 91/45, Washington, D.C.

Bana, I. M. and J. Handa (1990) "Currency substitution and transaction costs," *Empirical Economics* 15(3): 231–243.

Banerjee, A., Donaldo, J., Galbraith, J. W. and D. F. Hendry (1993) *Co-integration, error correction, and the econometric analysis of non-stationary data.* Oxford University Press: Oxford.

Bank of Latvia Monetary Review. URL: http://www.bank.lv/izdevumi/English/quarter/index1_96.html,index2_96.html,…, index4_98.html, index1_1999.html [17 June 1999]

Bank of Latvia, *Monetary Review*, RIGA, (3rd quarter) 1994, 1995.

Bank of Latvia, *Monetary Review*, RIGA, (all quarters) 1996.

Bartholdy, K. (1996) Statistical Review, *Economics of Transition*, Volume 4(1): 270–283, and Volume 4(2): 527–550.

Boero, G. and G. Tullio (1996) "Currency substitution and the demand for Deutsche marks before and after the fall of the Berlin Wall" in Mizen, P. and E. J. Pentecost (1996, pp.: 155–177).

Bordo, M. and E. Choudhri (1982) "Currency substitution and demand for money: some empirical evidence for Canada," *Journal of Money, Credit, and Banking* (14): 48–57.

Branson, W. H. and D. W. Henderson (1983) "The specification and influence of asset markets," in *Handbook of International Economics*, (eds.) R. W. Jones and P. B. Kenen (Amsterdam, North-Holland), pp. 749–806.

Bufman, G. and L. Leiderman (1992) "Simulating an optimizing model of currency substitution," *Revista de Analisis Economico* 7(1): 109–124.

Bufman, G. and L. Leiderman (1993) "Currency substitution under nonexpected utility: some empirical evidence," *Journal of Money, Credit, and Banking* (25): 320–325.

Calvo, G. A. (1985) "Currency substitution and the Real Exchange Rate: the Utility Maximization Approach," *Journal of International Money and Finance* 4(2): 175–188.

Calvo, G. A. and C. A. Rodriguez (1977) "A model of exchange rate determination under currency substitution and rational expectations," *Journal of Political Economy* 85(3): 617–624.

Calvo, G. A. and C. A. Vegh (1992) "Currency substitution in developing countries: an introduction," International Monetary Fund Working Paper, *IMF WP* 103/92/40, Washington, D.C.

Canzoneri, M. B. and B. T. Diba (1992) "The inflation discipline of currency substitution", European Economic Review 36(4): 827–846.

Central Statistical Bureau of Latvia. URL: http://www.csb.lv/basic.htm [22 July 1999]

Charemza, W. W. and S. Ghatak (1990) "Demand for money in dual-currency, quantity-constrained economy: Hungary and Poland, 1956-1985," *The Economic Journal* 100(December): 1159–1172.

Cuddington, J. (1983) "Currency Substitution, Capital Mobility and the Demand for Domestic Money," *Journal of International Money and Finance* (2): 111–133.

Cukierman, A., Kiguel, M. A. and N. Liviatan (1992) "How much to commit to an exchange rate rule? Balancing credibility and flexibility", Revista de Analisis Economico 7(1): 73–89.

Donaldo, J., Jenkinson, T. and Sosvill-Rivero, S. (1990) "Cointegration and Unit Roots," *Journal of Economic Surveys* 4, 249–73.

Doornik, J. A. and Hendry, D. F. (1997) *Modelling Dynamic Systems Using PcFiml 9.0 for Windows*, International Thomson Business Press: London.

*Economic Survey of Europe in 1993–1994*, UN Publication, New York and Geneva, 1994.

Enders, W. (1995) *Applied econometric time series*. John Wiley & Sons: New York.

Engle, R.F. (1992) "Estimating structural models of seasonality," in Hylleberg, S. (ed.) (1992, pp.: 291–319).

Ericsson, N. R. (1998) "Empirical modelling of money demand," *Empirical Economics* 23: 295–315.

Ericsson, N. R., Hendry, D. F. and G. E. Mizon (1998) "Exogeneity, Cointegration, and Economic Policy Analysis," *Journal of Business & Economic Statistics*, Volume 16(4): 370–387.

Ericsson, N. R., Hendry, D. F. and H-A. Tran (1994) "Cointegration, seasonality, encompassing, and the demand for money in the United Kingdom." Chapter 7 in Hargreaves, C. P. (ed.) *Nonstationary time series analysis and cointegration*, Oxford University Press: Oxford, pp.: 179–224.

Feenstra, R. C. (1986) "Functional equivalence between liquidity costs and the utility of money," *Journal of Monetary Economics* 17: 271–291.

Frenkel, J. A. and M. P. Taylor (1993) "Money demand and inflation in Yugoslavia, 1980-1989," *Journal of Macroeconomics* 15(3): 455–481.

Gilbert, C. L. (1990) "Professor Hendry's Econometric Methodology," in Granger, C. W. J. (ed.) (1990), pp. 285-90.

Giovannini, A. and B. Turtelboom (1994) "Currency substitution," in *The Handbook of International Macroeconomics,* ed. by F. van der Ploeg (Oxford: Basil Blackwell), pp. 390–436.

Granger, C. W. J. (ed.) (1990) *Modelling Economic Series: readings in econometric methodology*. Clarendon Press: Oxford.

Hamilton, J. D. (1994) *Time Series Analysis*. Princeton University Press, Princeton, New Jersey.

Hansen, L. P. (1982) "Large Sample Properties of GMM Estimators," *Econometrica* (50): 1029–1054.

Harvey, A. C. (1990a) *Forecasting, structural time series models and the Kalman filter*. Chapter 1, pp.: 1-2. Cambridge University Press: Cambridge.

Harvey, A. C. (1990b) *The econometric analysis of time series*. 2nd Ed. Hemel Hempstead: Philip Allan.

Hendry, D. F. (1995) *Dynamic Econometrics*. Oxford University Press, New York.

Hendry, D. F. and G. E. Mizon (1998) "Exogeneity, causality, and co-breaking in economic policy analysis of a small econometric model of money in the UK," *Empirical Economics* 23: 267–294.

Hendry, D. F. and J. A. Doornik (1994) "Modelling Linear Dynamic Econometric Systems," *Scottish Journal of Political Economy*, Volume 41(1): 1–33.

Hendry, D. F. and J. A. Doornik (1996) *Empirical Econometric Modelling Using PcGive for Windows.* International Thomson Business Press: London.

Hylleberg, S. (ed.) (1992) *Modelling Seasonality*. Oxford University Press, New York.

Imrohoroglu, S. (1994) "GMM Estimates of Currency Substitution between the Canadian Dollar and the U.S. Dollar," *Journal of Money, Credit and Banking*: 792–807.

Imrohoroglu, S. (1996) "International currency substitution and seigniorage in a simple model of money," *Economic Theory* 34(July): 568–578.

Kennedy, P. (1998) *A Guide to Econometrics.* 3rd Ed. Oxford: Blackwell.

Kouri, P. (1976) "The Exchange Rate and the Balance of Payments in the Short Run and the Long Run: A Monetary Approach," *Scandinavian Journal of Economics* 78: 280–304.

Lahiri, A. K. (1991) "Money and inflation in Yugoslavia," *IMF Staff Papers* 38(4): 751–788.

Mahdavi, M. and H. B. Kazemi (1996) "Indeterminacy and volatility of exchange rate under imperfect currency substitution," *Economic Inquiry* (1): 168–181.

Marquez, J. R. (1987) "Money demand in open economies: a currency substitution model for Venezuela," *Journal of International Money and Finance* 6(2): 167–178.

McKinnon, R. I. (1985) "Two concepts of international currency substitution," in *The Economics of the Carribean Basin*, (eds.) Connolly, M. D. and J. McDermott (New York, Praeger), pp.101–113.

McNelis, P. D. and C. Asilis (1992) "A dynamic simulation analysis of currency substitution in an optimizing framework with transaction costs," *Revista de Analisis Economico* 7(1): 139–152.

Melvin, M. and G. Afcha (1989) "Dollar Currency in Latin America," *Economics Letters* (31): 393–397.

Melvin, M. and K. Fenske (1992) "Dollarization and monetary reform. Evidence from the Cochabamba Region of Bolivia," *Revista de Analisis Economico* 7(1): 125–138.

Miles, M. A. (1978) "Currency substitution, flexible exchange rates, and monetary independence," *American Economic Review* (68): 428–436.

Ministry of Finance (Latvijas Republikas Finansu Ministrija). URL: http://www.fm.gov.lv/31pubper/vba1298a.html,vba0199a.html,..., vba0499a.html [22 July 1999]

Mizen, P. and E. J. Pentecost (1996) (eds.) *The macroeconomics of international currencies: theory, policy, and evidence.* Edward Elgar Publishing: Cheltenham, UK.

Mongardini, J. and J. Mueller (1999) "Ratchet Effects in Currency Substitution: An Application to the Kyrgyz Republic," International Monetary Fund Working Paper, *IMF Working Paper* 99/102, Washington, D.C.

Pagan, A. R. (1990) "Three Econometric Methodologies: A Critical Appraisal," in Granger, C. W. J. (ed.) (1990), pp. 99–104.

Rogers, J. H. (1996) "The currency substitution hypothesis and relative money demand in Mexico and Canada," in Mizen, P. and E. J. Pentecost (1996, pp.: 118–138).

Rogers, J.H. (1990) "Foreign inflation transmission under flexible exchange rates and currency substitution," *Journal of Money, Credit and Banking* 22(2): 195–208.

Rojas-Suarez, L. (1992) "Currency substitution and inflation in Peru," *Revista de Analisis Economico* 7(1): 153–176.

Sahay, R. and C.A. Vegh (1995) "Dollarization in Transition Economies: Evidence and Policy Implications," International Monetary Fund Working Paper, *IMF Working Paper* 103/95/96, Washington, D.C.

Sarajevs, V. (1999) "Macroeconomic Model of Transition Economy: A Stochastic Calculus Approach," Bank of Finland Institute for Economies in Transition (BOFIT) *Discussion Papers* No.7.

Savastano, M. A. (1992) "The pattern of currency substitution in Latin America: an overview," *Revista de Analisis Economico* 7(1): 29–72.

Savastano, M. A. (1996) “Dollarization in Latin America: Recent Evidence and Some Policy Issues,” International Monetary Fund Working Paper, *IMF Working Paper* 96/4, Washington, D.C.

Sturzenegger, F. (1992) “Currency substitution and the regressivity of inflationary taxation”, Revista de Analisis Economico 7(1): 177–192.

Sturzenegger, F. (1997) “Understanding the welfare implications of currency substitution”, Journal of Economic Dynamic and Control 21(2&3): 391–416.

Thomas, L.R. (1985) “Portfolio Theory and Currency Substitution,” *Journal of Money, Credit and Banking* 17(3): 347–357.

Uribe, M. (1997) “Hysteresis in a Simple Model of Currency Substitution,” *Journal of Monetary Economics* 40(1): 185–202.

# BOFIT Discussion Papers

## *1999*

*No 1* Tuomas Komulainen: Currency Crisis Theories – Some Explanations for the Russian Case

*No 2* Jukka Pirttilä: Tax Evasion and Economies in Transition: Lessons from Tax Theory

*No 3* Andrei Yakovlev: Black cash tax evasion in Russia: Its forms, incentives and consequences at firm level

*No 4* Barbara Lehmbruch: Managing uncertainty: Hierarchies, Markets and "Networks" in the Russian Timber Industry. 1991–1998

*No 5* Rupinder Singh – Juhani Laurila: Azerbaijan: Recent Economic Developments and Policy Issues in Sustainability of Growth

*No 6* Iikka Korhonen: Currency Boards in the Baltic Countries: What have we learned?

*No 7* Vadims Sarajevs: Macroeconomic Model of Transition Economy: A Stochastic Calculus Approach

*No 8* Ville Kaitila: Trade and Revealed Comparative Advantage: Hungary, the Czech Republic, and the European Union

## *2000*

*No 1* Victor Polterovich: Employment - wage decisions in the insider-owned firm

*No 2* Rupinder Singh: Bank Regulation, Compliance and Enforcement

*No 3* Terri Ziacik: An assessment of the Estonian investment climate: Results of a survey of foreign investors and policy implications

*No 4* Vadims Sarajevs: Econometric Analysis of Currency Substitution: A Case of Latvia

**BOFIT**
**Discussion Papers**
ISBN 951-686-922-X (print)
ISSN 1456-4564 (print)

ISBN 951-686-923-8(online)
ISSN 1456-5889 (online)

Editor-in-Chief **Jukka Pirttilä**

Bank of Finland Institute for Economies inTransition
(BOFIT)
P.O. Box 160
FIN-00101 Helsinki
Phone: +358 9 183 2268
Fax: +358 9 183 2294
bofit@bof.fi
www.bof.fi/bofit