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Policy analysis in real time using IMF's monetary model

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Abstract

We investigate to what extent estimated relationships of the IMF's monetary model and their policy implications are sample dependent. We observe that estimates of the model's key parameters and model-based measures of macroeconomic disequilibria are highly dependent on the data vintage employed. Changes in parameter estimates solely due to data revisions are found to be much smaller than those owing to parameter instability, possibly reflecting model misspecification. Moreover, instability in parameter estimates contributes to more uncertainty in assessments of macroeconomic disequilibria than data revisions. It is shown that analyses based on a version of the model in difference form are more robust across data vintages than those based on the standard version of the model with variables in levels. Still, they remain substantial from a policy perspective.

Keywords: *Real time data; Data and model uncertainty; IMF; Financial programming.*

JEL Codes: *C51, E41, E47, F17*

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1 Introduction

Information and due account of data revisions is important when drawing policy implications, as emphasized by recent research; see e.g. Orphanides (2001), Orphanides and van Norden (2002), Evans (1998) and Ghysels et al. (2002). It has been shown that apparently sound policy advice in real time can prove to be fallacious when evaluated in the light of revised data. So far, however, the literature on forecasting and policy analysis in the context of real time data has mostly, if not exclusively, focused on Taylor-type interest rate rules, Phillips curves and aggregate demand equations for industrialized countries. Little research has been conducted on the real time data implications for models used for policy analysis in developing and emerging economies.

This paper investigates how dependent policy analysis and evaluations based on the Polak model, also referred to as the IMF's monetary model, may be on data from different vintages; see Polak (1957, 1998). Specifically, we investigate how much estimates of key parameters of the Polak model and measures of economic disequilibria based on one data vintage change when data from a later data vintage is used. A 'vintage' refers to the data set available at a particular date, while 'real-time data' refers to a collection of such vintages. Later vintages contain more observations and cover longer sample periods than earlier vintages. In addition, later vintages may contain revised data relative to data from earlier vintages. In particular, we investigate the robustness of key parameter estimates and assessments of economic disequilibria to data revisions embedded in later data vintages. The paper sheds light on the scope for policy mistakes when the Polak model is used without adequate account of relevant country specific factors and data uncertainty.

The Polak model constitutes the foundation of the IMF's financial programming models, which are used to undertake policy analysis and offer policy advice to developing and emerging economies, especially those seeking IMF assistance; see e.g. Mikkelsen (1998), Mussa and Savastano (1999) and Rao and Nallari (2001, ch. 4). The policy advice often lays the foundation for short-run and medium-run policy actions aimed at correcting external imbalances and checking inflation. Such actions may be in terms of explicit or implicit quantitative targets for key variables including level or growth of public and private domestic credit, monetary aggregates, imports and nominal exchange rates. Sometimes, short-run and medium-run policy actions are part of long-run structural adjustment programs agreed upon between the IMF and assistance-seeking countries.

The model may also be used to evaluate macroeconomic performance in response to policy actions undertaken by governments receiving assistance from the IMF. Satisfactory macroeconomic performance as reflected in quantitative (intermediate) targets for key variables is often a prerequisite for the continuation of IMF assistance.[1,2] Evaluations of recent and likely future

[1] Polak (1991, p. 59) states that "The Fund's performance criteria have a precise meaning: unless they are met on the specified date, the next disbursement does not take place."

[2] A substantial number of IMF assistance programs have been revised and even suspended in response to large deviations from agreed-upon targets for key variables over the program period. For example, more than a third of all IMF support packages approved between 1973–1997 ended with disbursements of less than half of the initially

macroeconomic performance as well as of authorities' adjustment efforts are often conducted at quarterly intervals after the start of a program, which usually remains active for 1–3 years; see e.g. Polak (1991) and Mussa and Savastano (1999).

The Polak model has been quite influential for over a half century in policy analyses and evaluation; see Polak (1998), Mussa and Savastano (1999), Rao and Nallari (2001, ch. 4), Rowe (2008) and Boughton (2004). One of the advantages of the Polak model is its parsimony, which facilitates its communication, estimation and application to different countries with minor adjustments; see e.g. Polak (1998). This is especially important because high quality data may not be available for many developing and emerging economies for development of large and complex models and precise estimation of model parameters; see Polak (1991).

Financial or stabilization programs based partly on some version of the Polak model are not derived mechanically but also rely on considerable judgement to take into account a country's economic and political situation; see Mussa and Savastano (1999) and Polak (1991, 1998). Moreover, policy recommendations are reached in an iterative fashion over time in response to more information and changes in a country's circumstances and future prospects.

Still, the design and evaluation of economic adjustment programs seem to be vulnerable to data revisions. This is because economic adjustment programs are designed and evaluated using the latest estimates of the country's main economic variables and their short-term projections; see Mussa and Savastano (1999). The latest data, though important for policy analysis, are not necessarily accurate since, in general, there is a tradeoff between timeliness and accuracy of data.

Previously, a number of studies including Reinhart (1990) and Easterly (2006) have pointed out instability in parameter estimates of the Polak model due to structural changes and/or its possible misspecification. Potential changes in estimates of key parameters over time and across countries are also acknowledged by users of the Polak model embedded in financial programming models; see e.g. Khan et al. (1990), Mussa and Savastano (1999) and Polak (1998). However, it is assumed that the iterative nature of the financial programming approach and practitioners' willingness to amend the behavioral equations and adjust parameter estimates in the light of any available information may safeguard against policy errors. Moreover, it is assumed that it is sufficient for parameter estimates to be stable over the relatively short horizon of an economic adjustment program; see e.g. Khan et al. (1990) and Mussa and Savastano (1999).[3]

Our study may be considered an extension of earlier studies. It does not only examine possible changes in parameters and policy implications over time and across countries, but also across differ-

agreed support; see Mussa and Savastano (1999).

[3]For example, Khan et al. (1990) state that "While experience would lead one to reject the extreme view that the income velocity of money is constant, This does not materially affect the analysis. All that is needed in this framework is that the demand for money, or velocity, respond in a predictable fashion over the program period to changes in variables such as real income and prices..." However, our analysis implies that predictability based on a given data sample (vintage) may not be robust to data revisions.

ent data vintages for a given time period and country.[4] Moreover, it sheds light on to what extent the iterative nature of the financial programming approach and practitioners' use of judgement may help safeguard against policy errors. In particular, whether one is justified in assuming that its parameter estimates can be considered stable over the relatively short horizon of an economic adjustment program.

The limited availability of high quality data for developing and emerging economies makes it difficult, if not impossible, to examine policy advice in real time with the hindsight of mature data, which are the outcome of one or several revision rounds. Nevertheless, given the influence of the Polak model in policy formulation and evaluation of macroeconomic performance, it is important to shed light on how sensitive the model's key parameters and policy implications could be to data revisions. The model's key equations depend on a series that often undergoes the heaviest data revisions, namely GDP; cf. Croushore and Stark (2001) and Orphanides and van Norden (2002).

We employ real time data for the US and the UK to shed light on the issue. We conjecture that data and estimates of key parameters for developing and emerging economies are likely to be at least as sensitive to shifts in data vintages as those for the US, the UK and other industrialized countries.[5] These countries have more experience and better infrastructure for the compilation and processing of economic data than most of the developing and emerging economies. Yet, for example for US GDP, Croushore and Stark (2001) note that real GDP growth numbers have undergone substantial revisions even twenty years after their first release; the revisions have been within the range −5.5 to 8.5%.

Our findings support earlier studies pointing out instability in the parameter estimates over time and cross-country differences. Moreover, we find that measurement errors, as revealed by subsequent data revisions over many years, introduce substantial uncertainty about values of key variables and parameter estimates of a model, even for a given country and a given time period. Accordingly, one may not obtain relatively precise values of key macroeconomic variables, parameter estimates and forecasts until after several years. It is also found that revisions in variables may lead to substantial revisions in macroeconomic assessments in spite of stable parameter estimates. The latter finding suggests limitations on what a model builder can do to reduce the scope for policy errors, but supports the use of information in addition to that embedded in the model and data sample as well as the use of decision frameworks that explicitly acknowledge nonquantifiable data and/or model uncertainty; cf. Hansen and Sargent (2007).

It is important to clarify at the outset that we are not able to evaluate actual applications of financial programming models given the extensive use of judgement in the formulation and evalu-

[4] Easterly (2006), examining both the identities as well as the behavioral equations of the Polak model, has pointed out large statistical discrepancies in the accounting identities used in the model and that econometric estimates of key parameters often deviate significantly from their assumed values. Moreover, the estimates have been shown to differ notably across countries.

[5] We have also undertaken the investigation using real time for Norway. The results, available on request, were found to be comparable with those for the US and/or the UK.

ation of financial programs and the lack of real time data for developing and emerging economies. Our analysis is also limited as it only examines parts of a financial programming model, which would typically contain a large number of behavioral equations and accounting identities in addition to some versions of the behavioral equations of the Polak model. Furthermore, the analysis should not be considered a critique of the Polak model per se, as challenges posed by data subject to revisions would also be posed by any policy and forecasting model based on such data.

The remaining paper is organized as follows. In the next section, we present key behavioral relationships and parameters of the Polak model. Section 3 and Appendix 6 briefly present the quarterly real time data sets for the US and the UK and show the degree to which the data are affected by revisions. Section 4 presents our empirical analysis based on these real time data sets while Section 5 investigates the contribution of data revisions to our results. Section 6 concludes.

2 The Polak model: relationships and key parameters

The core stripped-down version of the Polak model consists of two behavioral equations. One behavioral equation is based on the quantity theory, characterizing the relationship between money, nominal GDP and the money velocity parameter. The other behavioral equation is a linear relationship between aggregate imports and nominal GDP, where the elasticity of imports with respect to nominal income is the key parameter. The core model version also includes two identities: the balance of payment identity and the monetary survey identity, which states that aggregate money equals net domestic credit and net foreign exchange reserves; see e.g. Khan et al. (1990) and Polak (1998). This study focuses on the behavioral equations, while the identities are the main subject of Easterly (2006).

In model applications, the velocity of money (V) may be inferred by taking the ratio of nominal GDP to a monetary aggregate:

$$V = PY/M, \tag{1}$$

where PY denotes nominal GDP, while M is a monetary aggregate, e.g. *M1* or *M2*. This relationship assumes income elasticity of money demand to be unity. Target values of monetary aggregates may be derived from such identities conditional on an estimate of velocity and some target values or projections of nominal income. Alternatively, one may calculate values of velocity using forecasts of money demand and nominal income to cross check their reasonability in the light of velocity values obtained. For simplicity, one may also set expected value of future velocity to its observed value at the end of the sample period, or equal to a sample average of its observed values; see e.g. Reinhart (1990).

The second key parameter is the income elasticity of imports, which follows from the assumption of a linear relationship between aggregate imports (B) and nominal GDP. The income elasticity of imports is often assumed to be one, or inferred by taking the ratio between imports and nominal GDP. Future values of the income elasticity of imports can be projected using techniques similar to that used for money velocity.

Estimates of income elasticities play a key role in projections of future money demand and imports. Thereby they also affect (e.g. ceilings on) the level of credit to the government and/or the private sector as well as foreign exchange rate policies aimed at achieving (e.g. some minimum level of) foreign reserves to pay for projected imports. For example, import projections may be used to infer the required devaluation of a currency to achieve external balance.[6]

We base our main analysis on (log) linear money demand and import functions where the assumption of unit elasticities of money and imports with respect to income may be relaxed. Such models are commonly used and have been formulated in (log) levels of the variables or in difference terms in the relevant literature; see e.g. Burth and Chadha (1989), Khan et al. (1990), Reinhart (1990), Mikkelsen (1998), Polak (1998) and Easterly (2006).

We consider the following static long-run relationships between money and nominal income and between imports and nominal income:

$$mi_t^v = \alpha_i + \beta_i py_t^v + \epsilon_{i,t}^v, \tag{2}$$

$$b_t^v = \alpha_b + \beta_b py_t^v + \epsilon_{b,t}^v, \tag{3}$$

where small letters indicate the corresponding variables in logs. The Greek letters α_i and α_b are intercept terms; β_i and β_b are the income elasticities of a monetary aggregate mi (e.g. $m0$, $m1$ and $m2$) and imports, respectively; while $\epsilon_{i,t}^v$ and $\epsilon_{b,t}^v$ are error terms. It follows that one may interpret $\epsilon_{i,t}^v$ as representing deviations from expected money velocity; cf. IMF (2004, p. 31). Superscript v and subscript t denote vintage and time period, respectively. The parameters, αs and βs, are assumed to be constant over time.

We examine variation in parameter estimates across different vintages and the validity of the posited long-run relationships, (2) and (3), by testing whether they can be considered cointegrating relationships based on data from different data vintages. It is commonly assumed that nominal GDP, money balances and imports are non-stationary integrated variables. We employ the two-step procedure of Engle and Granger (1987) to test for cointegration. Such an exercise may also shed light on previous studies of money and import demand using data from different vintages.

We also consider the models in difference form:

[6]This study is also relevant for the related literature on fundamental equilibrium real exchange rates. Models of fundamental equilibrium real exchange rates are often based on estimated trade equations; see MacDonald and Stein (1999) and the references therein. Information about the extent of revisions in domestic and foreign GDP and income elasticities of imports and exports may be helpful in assessing the data uncertainty associated with measures of real exchange rate misalignments.

$$\Delta_4 mi_t^v = \gamma_i \Delta_4 py_t^v + \varepsilon_{i,t}^v, \quad (4)$$

$$\Delta_4 b_t^v = \gamma_b \Delta_4 py_t^v + \varepsilon_{b,t}^v, \quad (5)$$

where Δ_4 is the 4th difference operator while $\varepsilon_{i,t}^v$ and $\varepsilon_{b,t}^v$ are error terms. We choose the fourth difference because our data is quarterly and it is easier to relate to per annum growth rates. The slope coefficients, γs, in these models can be interpreted as short-run elasticities of money and imports to income. It has been argued that such models with (constant) short-run point elasticities may be, or would have to be, relied upon to forecast variables of interest over relatively short horizons; cf. Mussa and Savastano (1999).[7]

In applications of the Polak model to developing countries with small and shallow credit markets, interest rates are not usually included in the money demand equations; see e.g. Polak (1998) and Mikkelsen (1998). And, for countries with fixed exchange rate regimes, exchange rates are not explicitly included in the import equations; see e.g. Khan et al. (1990) and Easterly (2006). Some studies, however, extend the simple version of the model with nominal interest rates and exchange rates; see e.g. Polak and Argy (1971), IMF (2004) and Mikkelsen (1998).

We control for possible effects of interest rates on money demand as well as money velocity by including nominal interest rates in the money demand equations (2) and (4). We also control for possible effects of exchange rates on imports by including nominal effective exchange rates in the import equations, (3) and (5), when estimating them.[8]

A priori, it is not possible to say whether analysis based on equations with variables in the difference form would be more robust to data revisions than those based on variables in the level form. On the one hand, revisions in levels of variables may be larger than revisions in their growth rates. A definitional change may show up as a persistent error in the level of e.g. GDP, money stock and imports, while it need not show up as an error in their growth rates; cf. Mankiw et al. (1984). If such persistent errors are not accounted for, they may lead to omitted-variable bias in parameter estimates. Therefore, modeling the rate of money and import growth rather than their levels may reduce the problem caused by redefinitions. For example, Howrey (1996) shows that forecasts of the level of GNP are much more sensitive to data revisions than forecasts of growth rates.

[7] Mussa and Savastano (1999) note "...there is no escape from assuming some degree of predictability of the demand for money, in accord with some quantifiable model. In particular, the numerical quasi ceiling for base money will require judgement about how the demand for money will behave over the coming two to four quarters. This involves, at least implicitly numerical values for the short-run point elasticities of money demand."

[8] Our conclusions are robust to the use of more general dynamic models for money and imports. Some studies employ dynamic versions of the models in log levels or in difference forms including several lags of the right-hand side and left-hand side variables in the equations (2)–(5). In particular, equilibrium correction models (ECMs) of money demand and import growth have been employed to explicitly embed long-run relationships in their dynamic models; see e.g. Mikkelsen (1998) and Qin et al. (2005). The ECM representation presupposes cointegration between the variables defining the long-run relationships.

On the other hand, equations with variables in levels estimated by OLS may be more robust to data revisions than those with variables in the difference form because of the super-consistency property of OLS estimators in the former case, especially if the measurement errors are stationary; c.f. Engle and Granger (1987). One may consider preliminary data releases to suffer from measurement errors relative to the corresponding final estimates or the "true" value of the variables. Thus, preliminary data releases of variables may be characterized as measured with classic errors-in-variables; c.f. Maravall and Pierce (1986). Such measurement errors may not only lead to omitted variable bias but also to simultaneity bias in OLS estimates of parameters by contributing to correlation between the error terms and the right-hand side variable(s). However, if the variables in the equations are cointegrated, OLS estimators would be super-consistent and diminish possible bias due to measurement errors. The super-consistency property would also diminish simultaneity bias that may arise because of the possible endogeneity of right-hand side variables including nominal GDP, which may be determined simultaneously with money and imports.

However, the super-consistency property of OLS estimators may not be strong in small samples; see e.g. Banerjee et al. (1993). Therefore, omitted-variable bias due to level shifts that are not accounted for and possible simultaneity bias due to measurement errors and right-hand side endogenous variables may not be negligible. To test the sensitivity of OLS parameter estimates to possible simultaneity bias, we employ the instrumental variable (IV) method to estimate the parameters of the models in levels as in difference forms. We estimate the models with the IV method using lagged values of e.g. nominal GDP from earlier vintages. This is based on the assumption that lagged values of e.g. nominal GDP level and growth are likely to be correlated with current dated values from later vintages, while measurement errors in lagged values from one vintage may not be correlated with measurement errors in future values of GDP from a later vintage.

2.1 Revisions in data and measures of macroeconomic disequilibria

To assess possible effects of data revisions on parameter estimates and the model's predictions of key variables, we assume the final vintage in our real time data sets to contain the "true" observations of the variables, in line with common practice; see e.g. Croushore and Stark (2001). Hence, the parameter estimates and model's predictions based on the final vintage (fv) can be considered as our reference values. The vintage of 2005q4 is the final vintage in our data sets.

We measure revisions in data from a vintage v relative to the data from the final vintage, fv, as:

$$rev\_X_t^v = X_t^v / X_t^{fv} - 1, \tag{6}$$

where $rev\_X_t^v$ denotes revision in the value of a variable X in period t from vintage v, X_t^v, relative to that from the final vintage, X_t^{fv}.

Measures of excess money and imports may be used as indicators for the prudence of monetary and fiscal policies and to evaluate macroeconomic performance in response to policy actions implied by an economic adjustment program and the authorities' adjustment efforts. Performance criteria are typically specified as quarterly ceilings on the expansion of net domestic credit of the central bank and as quarterly floors on net international reserves. They may also be specified as the desired path for monetary aggregates and imports; see e.g. IMF (2004, p. 19).

Excess money level or money growth can be defined as: $mi_t^v - \widehat{mi}_t^v$ and $\Delta_4 mi_t^v - \Delta_4\widehat{mi}_t^v$, respectively. Here, $\widehat{mi}_t^v$ and $\Delta_4\widehat{mi}_t^v$ denote the money level and money growth predicted by estimated versions of equations (2) and (4), respectively. The gaps $mi_t^v - \widehat{mi}_t^v$ and $\Delta_4 mi_t^v - \Delta_4\widehat{mi}_t^v$ are (technically) mispredictions of money level and money growth, respectively. Similarly, excess import level and growth can be defined as $b_t^v - \widehat{b}_t^v$ and $\Delta_4 b_t^v - \Delta_4\widehat{b}_t^v$, respectively, where $\widehat{b}_t^v$ and $\Delta_4\widehat{b}_t^v$ denote import level and import growth based on estimated version of equations (3) and (5). Variables with "^"s are model-consistent values of the corresponding macroeconomic variables.

Money stock or money growth differing (sizably) from the predicted level or from growth in money demand may be considered inconsistent with targets for inflation, domestic credit growth and net international reserves; see e.g. Mussa and Savastano (1999). Especially, a high level of import or import growth may make it difficult to maintain net international reserves above their specified floor level and hence be considered inconsistent with the desired path of international reserves over time. On the other hand, a lower level or growth in actual imports relative to corresponding values of predicted imports may lead to higher international reserves than targeted and thereby to a rise in money stock. It has been observed quite frequently that targets for e.g. broad money growth are overshot by wide margins often due to larger-than-expected increases in foreign assets; see e.g. Schadler (1996). A lower level or growth in actual imports than corresponding values of predicted imports can also be interpreted as an indication of structural impediments to the flow of imports, warranting changes in foreign trade policies.

Measures of excess money and imports, which are (technically) in-sample prediction errors, may also be considered indicators of the forecasting properties of their models. Money demand and import demand equations provide essential input to the process of designing and evaluating economic adjustment programs. For example, to set ceilings on domestic credit growth, an estimated money demand equation may be used to derive a reasonable path for a monetary aggregate under a program's assumptions regarding e.g. output growth and inflation. The ceiling on domestic growth may then be obtained by subtracting the floor on net international reserves from the desired path of the monetary aggregate; see e.g. Mussa and Savastano (1999).

Forecasts based on the behavioral equations are also used as reference values to cross check derived values of money and imports from the accounting identities, conditional on provided values for the remaining variables in the macroeconomic identities; see e.g. Easterly (2006). For example, if there is a deviation between the derived value of imports from the balance of payment identity, conditional on e.g. a preferred path for international reserves and assumed exports, assumptions about exports and/or capital flows may need to be reconsidered to make the derived import figures consistent with the predictions for demand for imports at the projected levels of output and prices.

Given that prediction errors may be useful statistics for diagnosing macroeconomic issues as well as econometric issues related to model specification, it is important to investigate how robust they would be to data revisions. To examine revisions in the (in-sample) prediction errors, alternatively in measures of excess money level and money growth, we report differences in money level and money growth gaps, from a vintage v to those from the final vintage (fv):

$$rev\_mi_t^v = (mi_t^v - \widehat{mi}_t^v) - (mi_t^{fv} - \widehat{mi}_t^{fv}), \tag{7}$$

$$rev\_\Delta_4 mi_t^v = (\Delta_4 mi_t^v - \Delta_4 \widehat{mi}_t^v) - (\Delta_4 mi_t^{fv} - \Delta_4 \widehat{mi}_t^{fv}). \tag{8}$$

As the disequilibrium from the estimated long-run relationship for money may be interpreted as money velocity, $rev\_mi_t^v$ may be considered revisions in money velocity while $rev\_\Delta_4 mi_t^v$ may be interpreted as revisions in velocity growth.

Revisions in excess import level and import growth are defined as the corresponding terms for money stocks; see equations (7)–(8). Specifically,

$$rev\_b_t^v = (b_t^v - \widehat{b}_t^v) - (b_t^{fv} - \widehat{b}_t^{fv}), \tag{9}$$

$$rev\_\Delta_4 b_t^v = (\Delta_4 b_t^v - \Delta_4 \widehat{b}_t^v) - (\Delta_4 b_t^{fv} - \Delta_4 \widehat{b}_t^{fv}), \tag{10}$$

where $(b_t^v - \widehat{b}_t^v)$ and $(\Delta_4 b_t^v - \Delta_4 \widehat{b}_t^v)$ represent import level and growth in excess of the predicted values implied by the estimated versions of their models: (3) and (5).

3 Real time data

The following subsections briefly present the quarterly real time data sets for the US and the UK used in our empirical analysis. It is shown that the variables considered, including monetary aggregates, undergo sizable revisions over time which tend to decline with the maturity of vintages. It is also shown that there is no general pattern in data revisions in real time data sets for the two countries examined. The pattern and size of revisions differ across countries and time series of variables considered.

3.1 The US

For the US, we have obtained seasonally adjusted data for nominal GDP (PY), nominal imports (B) and monetary aggregates ($M1$ and $M2$) from the Federal Reserve Bank of Philadelphia.[9] The data is quarterly for nominal GDP and imports but monthly for $M1$ and $M2$. We let monthly observations for the middle month in a quarter represent quarterly observations, in line with common practice. The data included in each vintage are those an economic analyst would have in the middle of each quarter. Thus the vintages correspond to data as they existed on e.g. November 15 1977, February 15, 1978, and so on. The US data set is well known and has been previously employed in a number of studies including Orphanides (2001), Orphanides and van Norden (2002), Clark and McCracken (2009) and the references therein. We refer to Croushore and Stark (2001) for more information about the different data vintages.

We use data vintages that were available in 1973q1, 1973q2, 1973q3,...2005q4. Each of the data vintage v, marked 1973q1, 1973q2,...,2005q4, contains time series of the relevant macroeconomic variables over the period 1972q4 to $v - 1q$, as there is a one-quarter publication lag for the first releases of the data. For example, the data vintage marked 1977q3 would contain observations for the period 1972q4–1977q2.

[Figure 1 about here.]

Figure 1 gives an impression of data revisions in US nominal GDP (PY), imports (B), $M1$ and $M2$. The figure presents their values from every vintage considered, 1973q1–2005q4, relative to the corresponding values from their final vintage: 2005q4. In precise terms, it shows values of $rev\_X_t^v$ which is defined in (6), where $X = PY$, B, $M1$ and $M2$. At each point in time there are z observations for every X which decline by one for every quarter as we go forward in time. That is, $z =$ Total vintages - p, where $p = 1, 2,...T$ indicates the period number. Thus, for period 1973q1 there would be 132 observations of X, while for period 2005q3 there would be just one observation of X, contained in the data vintage marked 2005q4.

Figure 1 shows that revisions in the US data can be substantial. Figures 1.a–b show that observations for PY and B from some vintages differ substantially from their final releases. In general, the extent of revisions for a particular period declines over time as the observations "mature", i.e. come from later vintages. In percentage terms, the nominal GDP revisions vary in the range –11 to 2%, while those for imports vary in the range –5 to 16%. Negative values imply underestimation relative to values from the final vintage. Accordingly, values of nominal GDP seem to have been mostly underestimated in earlier data vintages relative to the values in the final vintage. In contrast, import values seem to have been mostly overestimated in earlier vintages relative to the values in the final vintage. In the case of US GDP, we observe that contents of

[9]The data set can be downloaded from www.phil.frb.org/econ/forecast/reaindex.html.

vintages tend to converge towards that of the final vintage; earlier vintages differ more from the final vintage than later vintages. This is, however, not the case for US imports.

Figures 1.*c* suggests that revisions in *M1* are not negligible, being within the range –1 to 4%. Revisions in *M2* are mostly comparable to those in *M1* in size; see Figure 1.*d*. The exception is the vintages marked about 1978. The positive values of *M2* revisions from the early 1980s and mid-1990s vintages suggest that they overestimated money stock relative to the later vintages.

It follows that estimates of money velocity, which is a key parameter of the Polak model, are subject to substantial revisions. Values of *M1* velocity (*V1*) mostly reflect revisions in nominal GDP. This is also the case for the values of *M2* velocity (*V2*), except for the vintage marked 1978; see Figures 1.*e–f*. The figures show that revisions in velocity are in the range –14 to 3% in the case of *V1* and in the range –10 to 1% in the case of *V2*, except for the values implied by the 1978 vintage. We also note that velocity values derived from earlier vintages have tended to underestimate the velocities relative to those based on the final vintages.

3.2 The UK

For the UK, we employ seasonally adjusted quarterly data for real GDP (Y), the GDP deflator (P), $M0$, $M4$ and nominal imports (B). The series have been compiled by Garratt and Vahey (2006) except for nominal imports, which were initially compiled by Castle and Ellis (2002) but are updated and made available by the Bank of England.[10] The UK real time data is not as extensive as the US data. Real time observations for *M1* and *M2* are not readily available, while only a limited number of vintages are available for *M3*.

We use data vintages marked 1982q1, 1982q2, 1982q3,...2005q4. A data vintage v contains time series for the variables over the period 1973q1 to $v - 2q$, as there is a two-quarter publication lag for the first releases of the data.

[Figure 2 about here.]

Figure 2 provides an impression of the extent of data revisions in UK nominal GDP (PY), imports (B), $M0$ and $M4$; PY denotes the product of the real GDP series and the deflator. The figures show revisions in these variables relative to the final vintage (2005q4) over the period 1973q1–2005q2. Here, $rev\_X_t^v$ is defined by equation (6) for the case of the UK PY, B, $M0$ and $M4$.

Figure 2.*a* shows that the data revisions in the case of nominal GDP are in the range –20 to 3%. In particular, two of the data vintages from the late 1990s and early 2000s heavily underestimate nominal GDP relative to the final vintage. For the other vintages, the revisions remain mostly within the range –4 to 3%. Revisions in import figures are relatively small for the years up to the

[10] The import data has been downloaded from http://www.bankofengland.co.uk/statistics/gdpdatabase. The other series for the UK have been kindly provided by Shaun Vahey on request.

late 1980s, mostly within the range –0.5 to 1%; see Figure 2.*b*. Afterwards, however, the revisions are as large as –8% relative to the data points from the final vintage. Notably, the size of revisions, which in this case are underestimations relative to the final data points, seems to increase from the early 1990s to early 2000s.

Revisions in monetary aggregates are also sizeable, especially those in $M0$. Revisions in the UK $M0$ are mainly within the range –6 to 2% and mostly comparable to those for the US $M1$ in absolute terms; see Figure 2.*c*. The range of revisions in the UK $M4$ is somewhat smaller with most of the revisions occurring in vintages from the 1980s onwards; see Figure 2.*d*. In particular, large revisions are not confined to a few vintages and do not display any systematic trend as they do in the case of the US $M2$.

Values of *M0* velocity and *M4* velocity, *V0* and V4, respectively, undergo revisions in the ranges −20 to 5% and –18 to 3%, respectively; see Figures 2.*e*–*f*. However, most of the revisions are within the ranges –5 to 5% and –5 to 3%, respectively. Except for underestimation of the velocities by some data vintages, the revisions seem to be symmetric relative to velocity values based on data from the final vintage.

4 Policy analysis in real time

This section sheds further light on uncertainty in parameter estimates and policy analysis when they are based on all available observations of variables from the latest vintage at each point in time.[11] We estimate the models on all data from (almost) all available vintages for both of the countries. The start periods of the samples are kept fixed while the number of observations, and hence the length of sample periods, increases with the maturity of data vintages. We neglect some initial vintages in each of the real time data sets to obtain a sufficient number of observations for the estimation of parameters.

4.1 Shifts in estimates of long-run parameters

We first present estimates of intercepts terms and slope coefficients, which represent income elasticities of money demand and import demand; see equations (2)–(5). The estimates are based on equations where we have controlled for the effects of (nominal) interest rates and nominal effective exchange rates. The results would not have differed much if we had not controlled for the effects of these variables, which is not uncommon in applications of the Polak model.

Figure 3 suggests that estimates of intercept terms and slope coefficients in the money demand equations differ substantially across data vintages for the two countries. Overall, estimates of the

[11] For example, a hypothetical researcher conducting research in 1990q1 bases his/her analysis on the data from the vintage marked 1990q1 and employs data for the period 1973q1 to 1989q1. When conducting the research in 1997q4, the researcher bases the analysis on the vintage marked 1997q4 and employs data for the period 1973q1–1997q3 and so on.

intercept terms in the money demand equations are relatively more vulnerable than estimates of slope coefficients to changes in data vintages. For the US, the estimated intercept term in the $m1$ equation varies in the range –0.8 to 1.5, while the corresponding slope coefficient estimates vary in the range 0.6 to 0.9; see the top panel of Figure 3. In the case of the US $m2$ equation, estimates of the intercept term vary in the range –2 to 0.3 while the corresponding slope coefficient estimates vary in the range 0.9 to 1.17. In the case of the UK $m0$, the slope coefficient displays an inverse v-shape, which is also reflected in the corresponding intercept estimate. The slope coefficient varies in the range 0.62 to 0.72, while the intercept terms vary in the range –1.8 to –0.3. In the case of the UK $m4$, the intercept estimate changes (gradually) from –5 to –7, while the slope coefficient estimate changes from 1.07 to 1.22 when the sample varies with the vintage.

[Figure 3 about here.]

The results for all of the import demand equations but one suggest relatively small variation in estimates of slope coefficients across vintages; see the right-hand column of Figure 4. The exception is the case of US imports where the slope coefficient estimates vary from about 3.5 to 1.5. However, there is relatively little variation in the estimates of this slope coefficient in the vintages from 1990s onwards. In contrast, estimates of the intercept terms display relatively large variation across data vintages; see the left-hand column of Figure 4.

[Figure 4 about here.]

The magnitude of shifts in parameter estimates across data vintages were about the same when equations (2)–(5) were estimated by the instrument variable (IV) method, even though the IV parameter estimates did differ slightly from the corresponding OLS estimates; see e.g. Figures 10.b and 11.b. For brevity, we therefore do not display all IV estimates of the parameters.

We have also tested whether money demand and import equations for the US and the UK constitute statistically valid long-run, or cointegrating, relationships across different data vintages. Further details and results are presented in Appendix B.

In sum, the support for cointegration between the relevant variables in money demand equations has been found to be weak, if present at all, and highly dependent on data vintage and sample. The import demand equations have been supported in data across nearly all data vintages. The strength of the support for cointegration is, however, vintage-dependent. Moreover, there is relatively large variation in the corresponding estimates of the adjustment coefficients across data vintages suggesting a widely different speed of adjustment of actual imports to their model-based equilibrium values. In the case of US imports, estimates of the adjustment coefficient (mostly) vary in the range (–0.90, –0.1) while those for the UK imports vary in the range (–0.37, –0.15).

4.2 Shifts in estimates of short-run parameters

In the following, we estimate money demand and import demand equations in difference terms, assuming the differenced variables are stationary; see equations (4) and (5). Models in difference forms may be employed when cointegration between the variables in level is not supported, as in the case of the long-run money demand equations considered above.

The analysis sheds lights on to what extent models in difference forms are less susceptible to changes in data samples than models in levels. Variables (entering models) in difference terms such as growth rates often undergo smaller data revisions than variables in levels that may experience level shifts due to data revisions. Such level shifts in variables may have considerable effects on estimates of intercepts, in particular, as observed in the case of the long-run money demand and import equations. The super-consistency property of the OLS estimator when the variables in levels are cointegrated could still have contributed to weakening the effect of data revisions on the parameter estimates, particularly the slope coefficients, which were found to be relatively stable. Such an effect would not be present when we estimate models in difference form representing relationships between stationary variables.

[Figure 5 about here.]

[Figure 6 about here.]

Figures 5 and 6 present estimates of the income elasticity of money demand and imports using the equations in difference form. The results suggest that estimates of the slope coefficients, representing short-run income elasticities of money and import demands, vary in about the same range when the models are estimated in difference forms as when they are estimated in levels. In particular, estimates of the income elasticity of UK money demand and imports are relatively more stable than those for the US, as in the case of the corresponding long-run income elasticities.

The approximately 95% confidence intervals for the estimated short-run income elasticities suggest that estimates for the US $m2$, and UK $m4$ are not statistically different from unity in most of the data vintages; see Figure 5. In contrast, income elasticity estimates for the US $m1$ and particularly those for the UK $m0$ are significantly below unity.

Results for the import demand equations suggest that estimates of the short-run income elasticity estimates for the UK are close to 0.9, but not significantly different from unity at about the 5% level of significance. In contrast, the short-run estimates for the US are close to 1.5 and significantly different from unity at the 5% level of significance. The variation in income elasticity estimates across countries and their estimated levels are consistent with much earlier evidence; see e.g. Goldstein and Khan (1985) and Marquez (2002).

4.3 Revisions in measures of macroeconomic disequilibria

Figures 7–9 present revisions in measures of disequilibria in money stock, money growth and import level and import growth. These revisions reflect revisions in their models' left-hand side and right-hand side variables as well as their parameter estimates. Our overall impression is that real time analyses, employing all available observations from the latest vintages at each point in time, are prone to large and persistent revisions. Characteristics of revisions in measures of excesses differ widely across data vintages, countries, monetary aggregates and depend on whether the variables are in levels or in difference terms. In particular, revisions in excess money and import growth rates are smaller and less persistent than those in excess money stocks and import levels.

In detail, for the US *m1* and *m2*, the top panel of Figure 7 shows revisions in excess money stocks in the ranges –14 to 10% and –9 to 6%, respectively. As expected, underestimation of GDP and overestimation of money and vice-versa, tend to amplify revisions in macroeconomic excesses; cf. Figures 1–2. For the UK *m0* and *m4*, revisions in excess money stocks are in the ranges -14 to 17% and -12 to 20%, respectively. In contrast, revisions in excess money growth for both the US and the UK are mostly within the range -4 to 4% and often within the even smaller range –2 to 2%; see Figure 8. This suggests that revisions in measures of excess money in growth form are mostly around 1/4 of revisions in excess money stocks. Figure 9 suggest comparable results for the case of US and UK imports. It shows the ranges of revisions in measures of excess import level to be about –17 to 20% and –16 to 13%, respectively, for the US and the UK. In contrast, revisions in excess growth rates of imports are mostly within the range -4 to 4%, but occasionally the revisions in the excess import growth for the US are as large as -27% and 8%.

Even though revisions in measures of excess growth rates are substantially smaller than corresponding levels, they remain substantial from a policy perspective. Notably, the extent of revisions in measures of excess money growth rates as well as for revisions in their levels for the two different countries are sizable fractions of target rates for broad money growth and misses from such targets for countries that recently underwent economic adjustment programs; see e.g. IMF (2004). For IMF supported programs during the period 1995–2000, target rates of broad money growth in the year following the program approval were in the range 10–16%, while projection errors or misses from targets for broad money growth were in the range –7 to 15%, except in one case where the projection error was 25%; see IMF (2004, Tables 8 and 10).

[Figure 7 about here.]

[Figure 8 about here.]

[Figure 9 about here.]

5 Contribution of data revisions

Revisions in parameter estimates could be due to changes in the sample period and length associated with changes in data vintages and/or due to data revisions. In the following, we investigate the contribution of data revisions to revisions in parameter estimates and measures of disequilibria. To this end, we fix the sample period and (hence) the number of observations and make estimates and predictions by only varying the data vintage. In this exercise, we choose data vintages from the later periods to obtain a sufficient number of observations for model estimation. Specifically, we fix the sample periods to be 1973q1–1989q4 and examine effects of estimating models on data vintages marked 1990q1–2005q4. The conclusions are qualitatively not sensitive to the choice of the sample period.

In sum, we find the contribution of data revisions to revisions in parameter estimates to be relatively small and most of the parameter estimates, especially those of slope coefficients, to be relatively stable in response to data revisions. Hence, revisions in measures of economic excesses observed in Figures 7–9 are mostly due to revisions in values of variables entering the models. However, the revisions in measures of economic excesses solely due to data revisions, though small, remain substantial from a policy perspective.

In detail, Figures 10 and 11 suggest that the contribution of data revisions to revisions in the parameter estimates is small, except in the case of the intercept term of US $m2$ and the US imports. The estimated intercept shifts from about –0.6 to –0.3 in the former case and in the range –0.1 to 0.5 in the latter case solely due to data revisions. Slope coefficients in equations of money demand and imports are relatively robust to data revisions. This also applies to estimates of slope coefficients in equations of growth in money and imports (not reported).

[Figure 10 about here.]

[Figure 11 about here.]

The evidence of relatively small effects of data revisions on parameter estimates, especially of slope coefficients, presented in Figures 10 and 11 are based on fixed sample sizes of about 20 years: 1973q1–1989q4. One could argue that the effects of measurement error as represented by data revisions on parameter estimates largely average out on samples of such sizes leaving parameter estimates relatively unaffected by data revisions associated with different data vintages. However, we reached the same conclusions by estimating the models on sample periods of 5 years using data from data vintages marked 1990q1–2005q4, as above.[12]

[12] The evidence is available on request.

5.1 Revisions in measures of disequilibria

Revisions in measures of economic excesses are mostly due to revisions in values of the variables entering the models. This is because the contributions of revisions in parameter estimates due to data revisions are relatively small in these revisions, as the parameter estimates are relatively robust to data revisions. Observed revisions in excess levels and growth rates of money and imports will therefore mainly reflect revisions in values of the variables entering the model and hence be sample dependent.

Reflecting relatively small data revisions in the vintages marked 1990q1–2005q4, Figures 12 and 13 show that the ranges of revisions in both excess money stock and money growth rates for the US solely due to data revisions are mostly in the range –1 to 1% while those for the UK are mostly within the range –2 to 2%. For import level and import growth, however, Figure 14 shows that revisions solely due to data revisions are within the range –4 to 4% for US imports and within the range –1.5 to 1.5% in the case of UK imports.

[Figure 12 about here.]

[Figure 13 about here.]

[Figure 14 about here.]

6 Conclusions

We have investigated the scope for policy mistakes when policy is based on the Polak model, the core of the IMF's financial programming models, estimated on real-time data that may be subject to revisions. To this end, we have estimated key parameters of the Polak model and derived measures of disequilibria in money stock and growth as well as import level and import growth using real-time data for the US and the UK. Data revisions are sizable even in data from the US and the UK and may be even larger for developing and emerging economies for which sufficient real time data is not available.

We have documented substantial changes in estimates of key parameters and revisions in the measures of disequilibria across different vintages of real-time data. Revisions in measures of disequilibria reflect data revisions as well as changes in parameter estimates. Changes in estimates of key parameters are mostly associated with changes in the estimation period owing to changes in data vintages. These changes may be reflecting structural changes in the economy not taken into account by the model and/or misspecification of the model due to e.g. omission of relevant variables and functional-form misspecification. Changes in coefficients estimates solely due to revisions in data have been found to be relatively small. Therefore revisions in measures of disequilibria solely due to data revisions are relatively small given the relative stability of parameter estimates in the face of data revisions, ceteris paribus.

In particular, we find that estimates of intercept terms display more variation across data vintages due to changes in the estimation period and data revisions. Estimates of slope coefficients have been found to be relatively more stable than estimates of intercept terms, especially when we control for possible effects of the estimation period. Intercepts terms play a key role in the predictive ability of models and hence in assessments of possible disequilibria; see e.g. Hendry (1997). Accordingly, we observe relatively large and quite persistent revisions of macroeconomic excesses when the model in level form is examined on different data vintages. When models in difference forms are used, revisions of macroeconomic excesses become much smaller and less persistent across data vintages. This is mainly due to elimination of intercepts terms from the models in difference form and the observation that variables in difference form entering the model are less susceptible to data revisions than when they are in levels.

Given the relatively large contribution of parameter instability to potential policy mistakes one may conclude that a model builder should seek to eliminate avoidable sources of instability in parameter estimates such as neglect of known structural changes in the economy and model misspecification owing to omission of relevant variables and inadequacy of functional form. Relevant economic theory and econometric techniques may help reduce if not eliminate potential model misspecification. Models with variables in difference form with or without intercept terms may be considered as an alternative to models with variables in levels or to cross check results based on such models.

Yet, even though models with variables in difference form have been shown to be more robust to data revisions than models with variables in levels, substantial uncertainty in parameter estimates and measures of disequilibria may remain. One may therefore consider applying decision frameworks that explicitly acknowledges model and or data uncertainty and formulate policies that could be robust to such uncertainty. This paper also underscores the need for employing a broad set of supplementary information in addition to macroeconomic data and the continuous use of judgement to formulate a policy response that is robust to data and model uncertainty.

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References

Banerjee, A., J. Dolado, J. W. Galbraith, and D. F. Hendry (1993). *Co-integration, Error Correction, and the Econometric Analysis of Non-stationary Data: Advanced Texts in Econometrics*. Oxford: Oxford University Press.

Boughton, J. M. (2004). The IMF and the force of history: Ten events and ten ideas that have shaped the institution. Working Paper 75, IMF.

Burth, R. C. and B. Chadha (1989). A simulation model for financial programming. Working Paper 89/24, IMF.

Castle, J. and C. Ellis (2002). Building a real time data base for GDP (E). In Bank of England (Ed.), *Quarterly Bulletin*, pp. 42–49. London: Bank of England.

Clark, T. E. and M. W. McCracken (2009). Tests of equal predictive ability with real-time data. *Journal of Business and Economic Statistics 27*, 441–454.

Croushore, D. and T. Stark (2001). A real-time data set for macroeconomists. *Journal of Econometrics 105*, 111–130.

Easterly, W. (2006). An identity crisis? examining IMF financial programming. *World Development 34*, 964–980.

Engle, R. F. and C. W. J. Granger (1987). Co-integration and error-correction: Representation, estimation and testing. *Econometrica 55*, 251–276.

Evans, C. L. (1998). Real-time Taylor rules and the federal funds futures market. *Federal Reserve Bank of Chicago Economic Perspectives Third Quarter*, 44–55.

Fischer, S. (1997). The real-time predictive content of money for output. *Journal of Monetary Economics 48*, 3–24.

Garratt, A., G. Koop, and S. P. Vahey (2008). Forecasting substantial data revisions in the presence of model uncertainty. *Economic Journal 118*, 1128–1144.

Garratt, A. and S. P. Vahey (2006). UK real-time macro data characteristics. *Economic Journal 116*, F119–F135.

Ghysels, E., N. R. Swanson, and M. Callan (2002). Monetary policy rules with model and data uncertainty. *Southern Economic Journal 69*, 239–265.

Goldstein, M. and M. Khan (1985). Income and price effect in foreign trade. In R. W. Jones and P. Kenen (Eds.), *Handbook of International Economics*, pp. 1042–1099. Amsterdam: North Holland.

Hansen, L. P. and T. J. Sargent (2007). *Robustness*. Princeton: Princeton University Press.

Hendry, D. F. (1997). The econometrics of macroeconomic forecasting. *The Economic Journal 107*, 1330–1357.

Howrey, E. (1996). Forecasting GNP with noisy data: a case study. *Journal of Economic and Social Measurement 22*, 181–200.

IMF (2004). Macroeconomic and structural policies in Fund-supported programs: Review of experience. Technical Report http://www.imf.org/external/np/pdr/2004/eng/macro.pdf, International Monetary Fund.

Khan, M. S., P. Montiel, and N. U. Haque (1990). Adjustment with growth: Relating the analytical approaches of the IMF and the World Bank. *Journal of Development Economics 32*, 155–179.

MacDonald, R. and J. L. Stein (1999). *Equilibrium Exchange Rates*. The Netherlands: Kluwer Academic Publishers.

Mankiw, N. G., D. Runkle, and M. D. Shapiro (1984). Are preliminary announcements of money stock rational forecasts? *Journal of Monetary Economics 14*, 15–27.

Maravall, A. and D. A. Pierce (1986). The transmission of data noise into policy noise in U.S. monetary control. *Econometrica 54*, 961–979.

Marquez, J. (2002). *Estimating Trade Elasticities.* Heidelberg, Germany: Springer.

Mikkelsen, J. G. (1998). A model for financial programming. Working Paper 98/80, IMF.

Mussa, M. and M. Savastano (1999). The IMF approach to economic stabilization. Working Paper 99/104, IMF.

Orphanides, A. (2001). Monetary policy rules based on real-time data. *Americal Economic Review 91*, 964–985.

Orphanides, A. and S. van Norden (2002). The unreliability of output gap estimates in real time. *Review of Economics and Statistics 84*, 569–583.

Polak, J. (1957). Monetary analysis of income formation and payments problems. *Staff Papers - International Monetary Fund 6*, 1–50.

Polak, J. (1998). The IMF monetary model at 40. *Economic Modelling 15*, 395–410.

Polak, J. and V. Argy (1971). Credit policy and the balance of payments. *IMF Staff Papers 16*, 1–24.

Polak, J. J. (1991). The changing nature of IMF conditionality. Essays in International Finance 184, Princeton University.

Qin, D., P. Quising, X. He, and S. Liu (2005). Modeling monetary transimission and policy in China. *Journal of Policy Modeling 27*, 157–175.

Rao, M. J. M. and R. Nallari (2001). *Macroecnomic Stabilizationa and Adjustment.* Oxford: Oxford University Press.

Reinhart, C. (1990). A model of adjustment and growth: An empirical analysis. *Staff Papers, International Monetary Fund 37*, 168–182.

Rowe, J. L. (2008). A legacy of model development. *Finance and Development June*, 4–7.

Schadler, S. (1996). How successful are IMF-supported adjustment programs? *Finance and Development 33*, 14–17.

Appendix A: Real time data for the US and the UK

The US GDP data undergoes a continual process of revisions owing to regular and benchmark revisions. It usually undergoes regular revisions for up to three years after the first releases of the data as more information comes along and the source data become more complete. In addition to regular schedules of revisions, there is a benchmark revision about every five years for the national income and product accounts, when earlier observations may be revised. Benchmark revisions incorporate new source data, possible changes in definitions of variables and changes in methodology aimed at improving the quality of data. Benchmark revisions may affect data releases over several years. For example, the October 1999 revisions raised the average growth rate of real output over the previous two decades; see e.g. for more details Croushore and Stark (2001).

As for GDP, there are two reasons for revisions in monetary aggregates. First, one receives additional data on the money stock and corrects computational and reporting errors. The data from these reports are processed irregularly with a lag of up to a year. And second, occasionally the definition of a money aggregate also changes. For example, the definition of $M1$ changed in important ways after 1978. Revisions in money stock data have been analyzed by e.g. Mankiw et al. (1984), Maravall and Pierce (1986) and Fischer (1997).

Like the US data, the UK data undergo revisions many years after their first releases. The UK data are, however, less subject to comprehensive benchmark revisions after about every five years. Nevertheless, comprehensive revisions including changes in methodology were undertaken in the late 1980s and early 1990s. The money series have also been affected by periodic re-classifications, many owing to financial innovations. Data revisions in the UK time series have been discussed in e.g. Garratt and Vahey (2006) and Garratt et al. (2008).

Appendix B: Money and import demand equations - valid long-run relationships?

We estimate static equations like (2)–(3) using the available money and import aggregates for the US and the UK and test whether the corresponding residuals may be considered stationary variables; see Engle and Granger (1987). In the latter test, we employ augmented Dickey-Fuller (ADF) models formulated as:

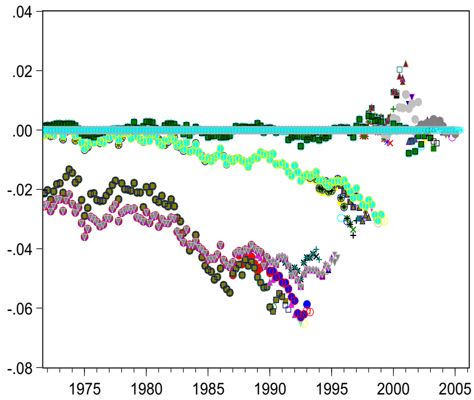
$$\Delta u_{j,t} = \varrho u_{j,t-1} + \sum_{l=1}^{k} \psi_{j,t-l} \Delta u_{j,t-l} + \xi_{j,t}, \tag{11}$$

where $u_{j,t}$ denotes the residual from the static equation for a money or import aggregate j. $\xi_{i,t}$ refers to the error term in the equation which is assumed to be a white noise, once enough lags (k) of Δu_j have been included to account for possible persistence in it. We use Dickey-Fuller distribution to test the null hypothesis of no cointegration: $\varrho = 0$. When estimating (11) for different residuals, we set the maximum number of lags, k, to 4 in all of the models.

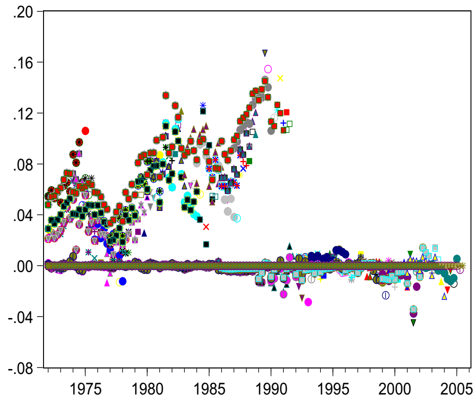
Figures 15–16 present estimates of the adjustment coefficients, denoted by $\widehat{\varrho}$s, and the corresponding t-values from the second step of the Engle-Granger procedure. These are denoted as $t\text{-}ADF$ values.

[Figure 15 about here.]

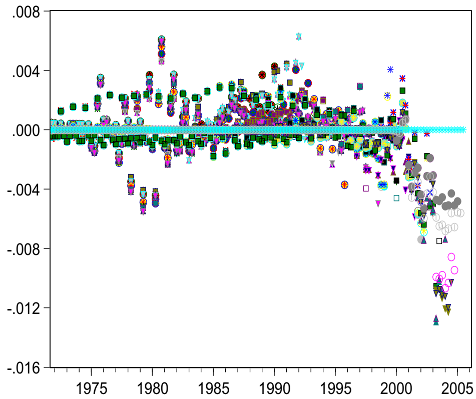
[Figure 16 about here.]



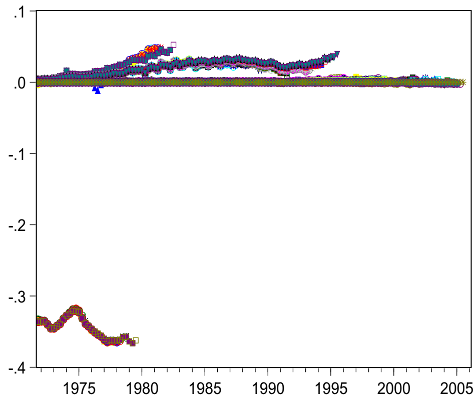
(a) US: GDP



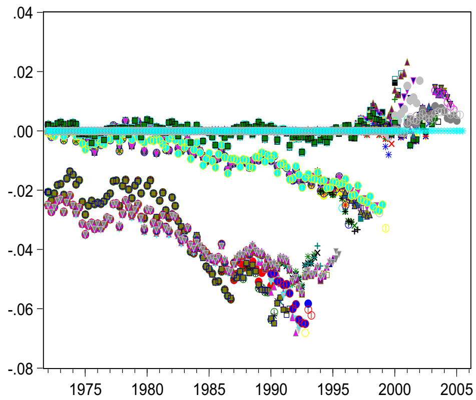
(b) US: Imports



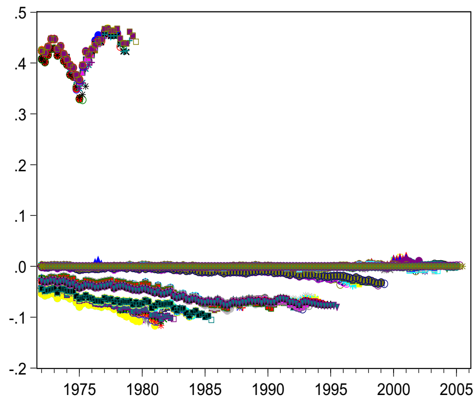
(c) US: M1



(d) US: M2

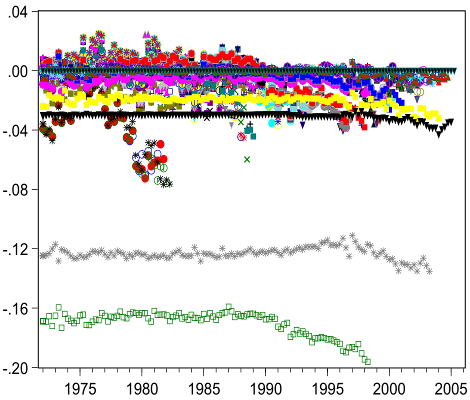


(e) US: V1

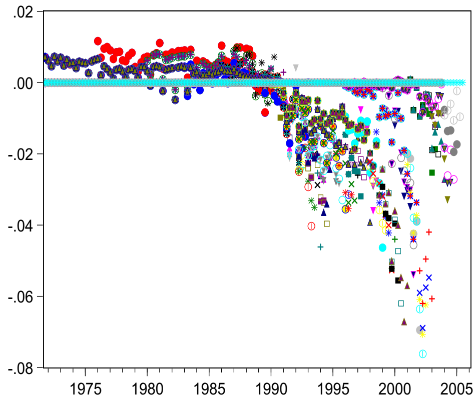


(f) US: V2

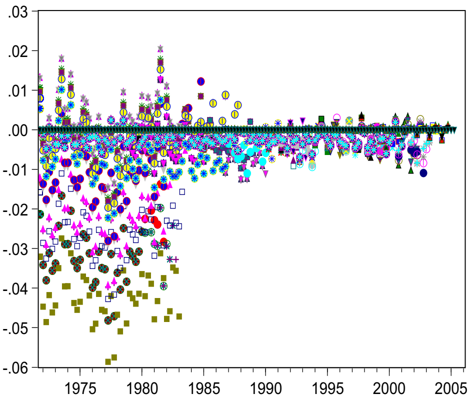
Figure 1: Revisions in the US data. Observations from vintages marked 1973q1–2005q4 are measured relative to the final vintage, 2005q4; cf. equation (6). A vintage marked period v contains observations for the period 1972q4 to $v-1$. Observations from different vintages are distinguished by different symbols and shades. The horizontal axes present periods of observations.



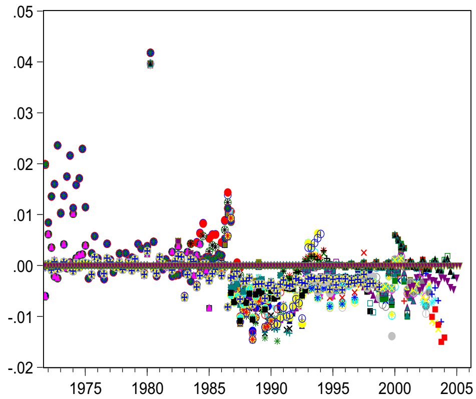
(a) UK: GDP



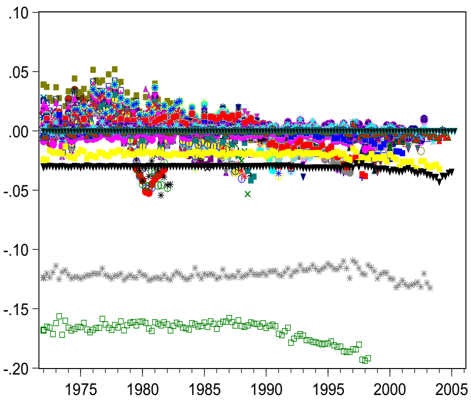
(b) UK: Imports



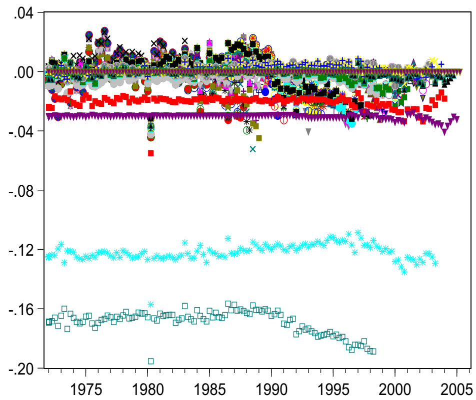
(c) UK: M0



(d) UK: M4

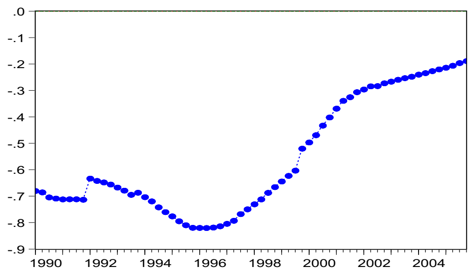


(e) UK: V0

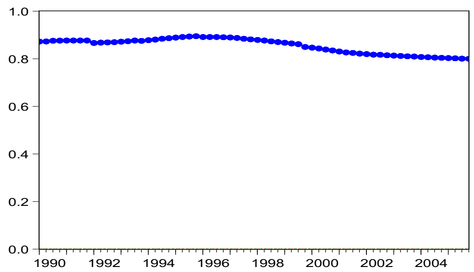


(f) UK: V4

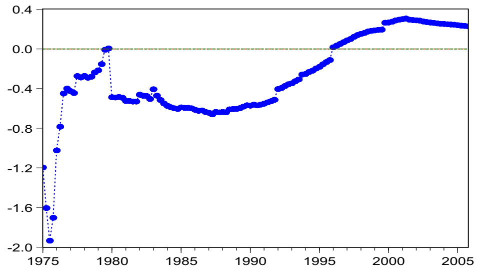
Figure 2: Revisions in the UK data. Observations from vintages marked 1982q1–2005q4 are measured relative to the final vintage, 2005q4; cf. equation (6). A vintage marked period v contains observations for the period 1972q4 to $v-2$. Observations from different vintages are distinguished by different symbols and shades. The horizontal axes present periods of observations.



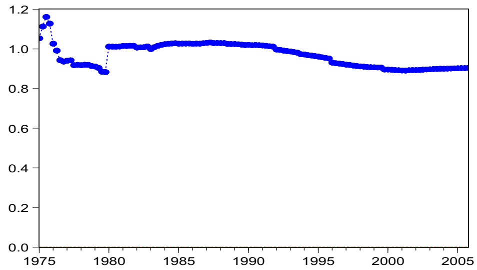
(a) US: $\widehat{\alpha_1}$



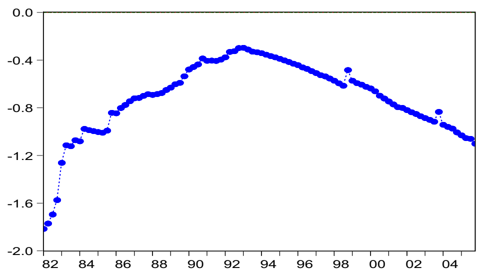
(b) US: $\widehat{\beta_1}$



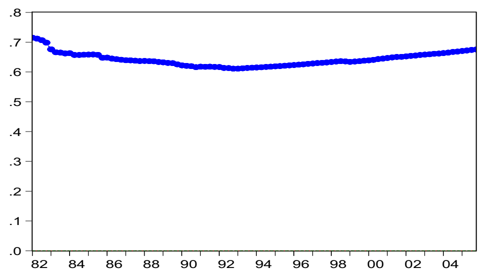
(c) US: $\widehat{\alpha_2}$



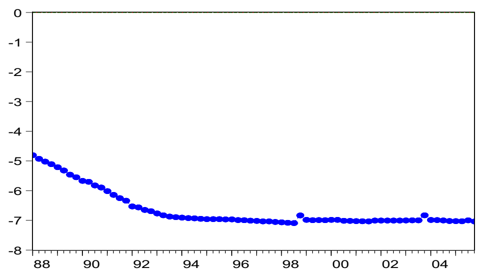
(d) US: $\widehat{\beta_2}$



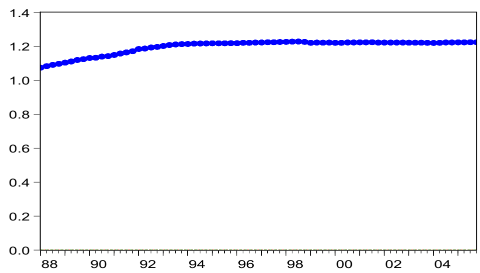
(e) UK: $\widehat{\alpha_0}$



(f) UK: $\widehat{\beta_0}$

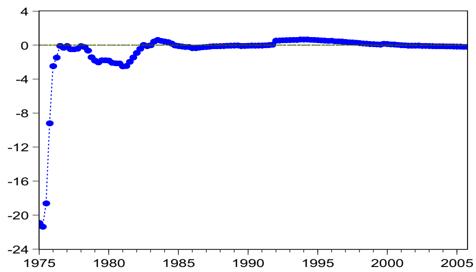


(g) UK: $\widehat{\alpha_4}$

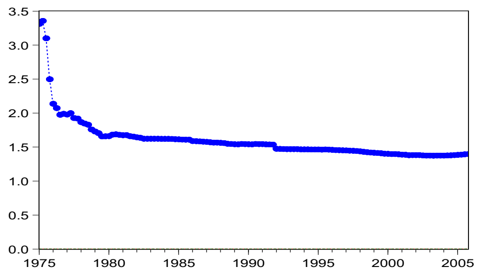


(h) UK: $\widehat{\beta_4}$

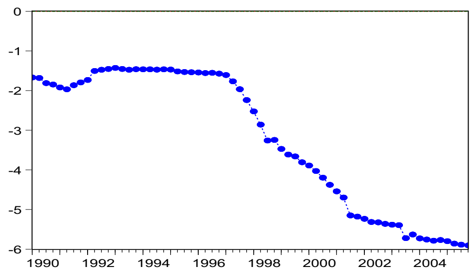
Figure 3: Estimates of intercept terms and income elasticities of the US $m1$ and $m2$ aggregates and the UK $m0$ and $m4$ aggregates based on data from different data vintages; see equation (2). Each dot represents an estimate based on a sample from a different data vintage, marked on the horizontal axes. The estimates are based on observations and sample periods that increase with the maturity of the vintages.



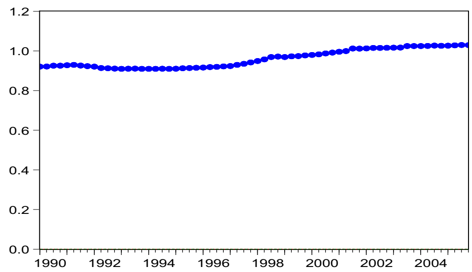
(a) US: $\widehat{\alpha_b}$



(b) US: $\widehat{\beta_b}$

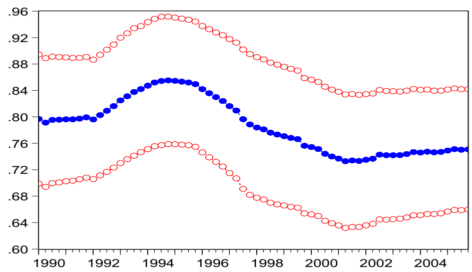


(c) UK: $\widehat{\alpha_b}$

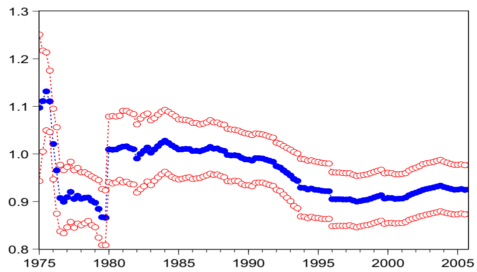


(d) UK: $\widehat{\beta_b}$

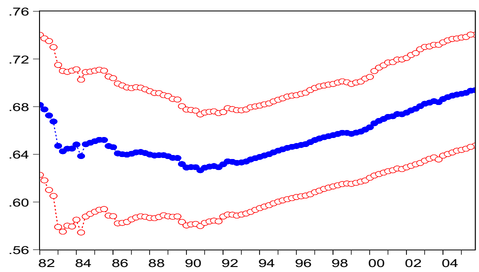
Figure 4: Estimates of intercept terms and income elasticities of imports of the US and the UK based on data from different data vintages; cf. equation (3). Each dot represents an estimate based on a sample from a different data vintage, marked on the horizontal axes. The estimates are based on observations and sample periods that increase with the maturity of the vintages.



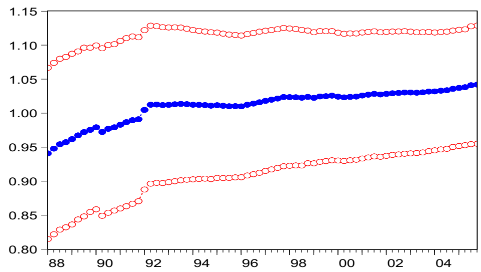
(a) US: $\widetilde{\beta_1}$



(b) US: $\widetilde{\beta_2}$

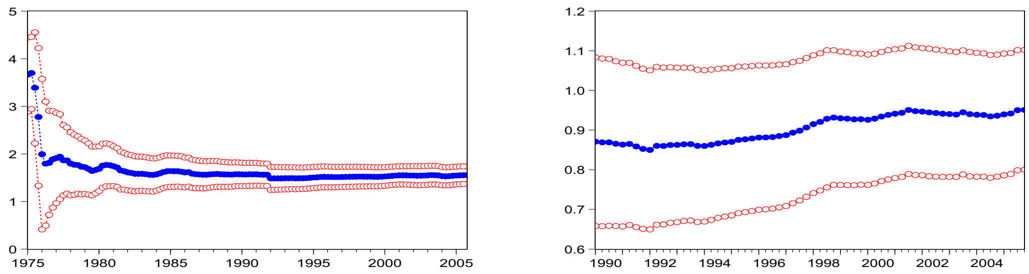


(c) UK: $\widetilde{\beta_0}$



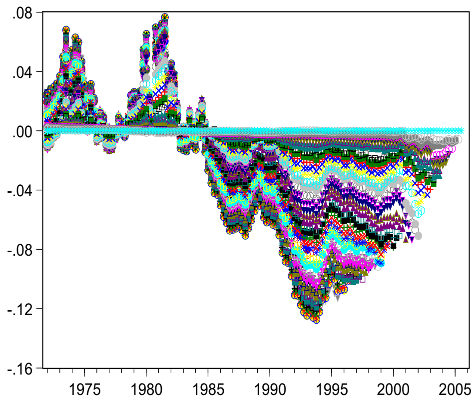
(d) UK: $\widetilde{\beta_4}$

Figure 5: Estimates of short-term income elasticities, together with $\pm$ 2 times their standard errors, of monetary aggregates of the US and the UK based on data from different data vintages; cf. equation (4). Each dot represents an estimate based on a sample from a different data vintage, marked on the horizontal axes. The estimates are based on observations and sample periods that increase with the maturity of the vintages.

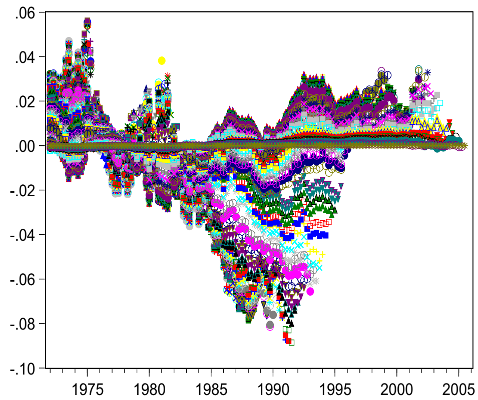


(a) US: $\widetilde{\beta_b}$ *(b)* UK: $\widetilde{\beta_b}$

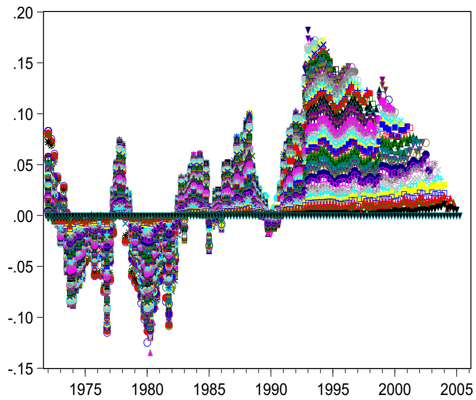
Figure 6: Estimates of short-term income elasticities, together with ± 2 times their standard errors, of imports of the US and the UK based on data from different data vintages; cf. equation (5). Each dot represents an estimate based on a sample from a different data vintage, marked on the horizontal axes. The estimates are based on observations and sample periods that increase with the maturity of the vintages.



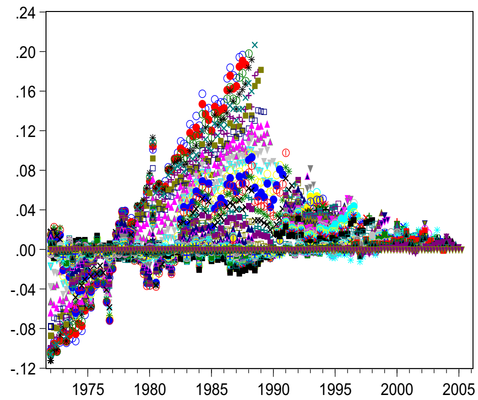
(a) US: $m1 - \widehat{m1}$



(b) US: $m2 - \widehat{m2}$

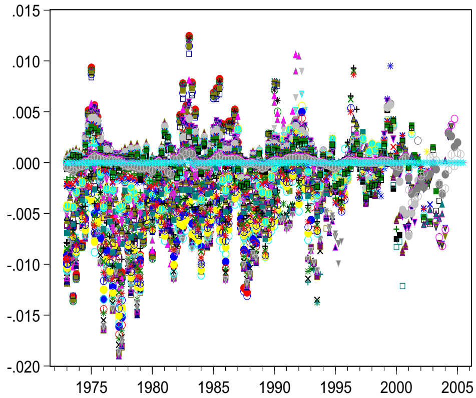


(c) UK: $m0 - \widehat{m0}$

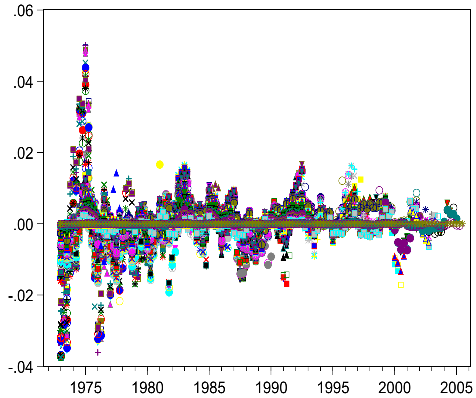


(d) UK: $m4 - \widehat{m4}$

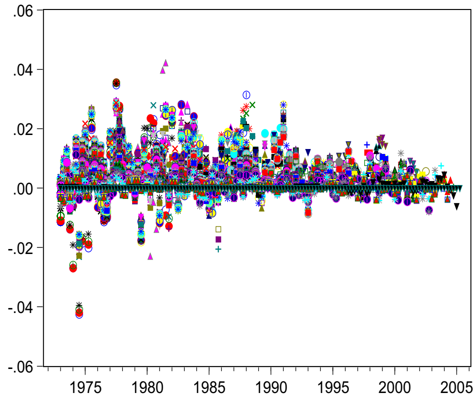
Figure 7: Revisions in the prediction errors ('disequilibria') for log values of monetary aggregates for the US and the UK based on their long-run relationships; cf. equation (7). Prediction errors for models estimated on data vintages marked 1973q1–2005q4 are measured relative to those estimated on the final vintage, 2005q4. Revisions in prediction errors corresponding to different vintages are distinguished by different symbols and shades. The horizontal axes present periods for the predicted values.



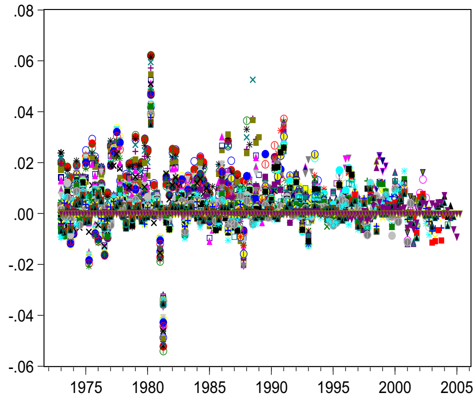
(a) US: $\Delta_4 m1 - \widehat{\Delta_4 m1}$



(b) US: $\Delta_4 m2 - \widehat{\Delta_4 m2}$

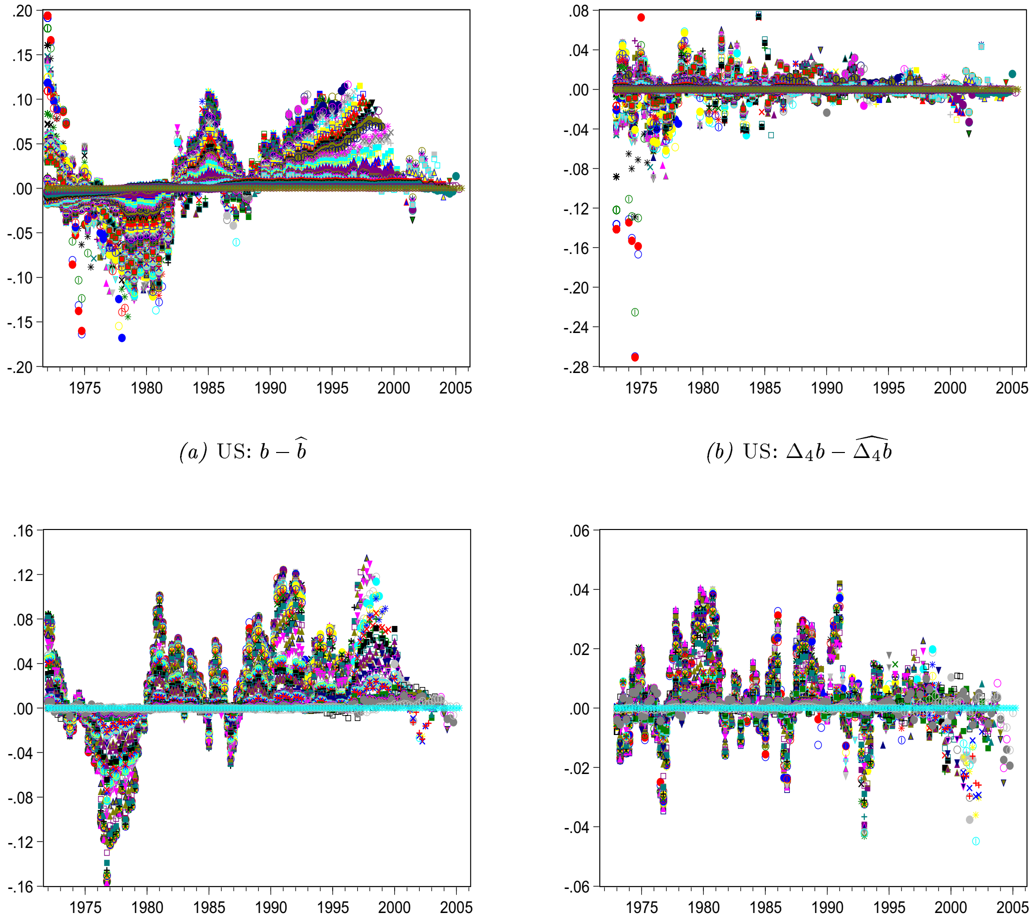


(c) UK: $\Delta_4 m0 - \widehat{\Delta_4 m0}$



(d) UK: $\Delta_4 m4 - \widehat{\Delta_4 m4}$

Figure 8: Revisions in the prediction errors ('disequilibria') for growth rates of monetary aggregates for the US and the UK based on their short-run relationships; cf. equation (8). Prediction errors for models estimated on data vintages marked 1973q1–2005q4 are measured relative to those estimated on the final vintage, 2005q4. Revisions in prediction errors corresponding to different vintages are distinguished by different symbols and shades. The horizontal axes present periods for the predicted values.



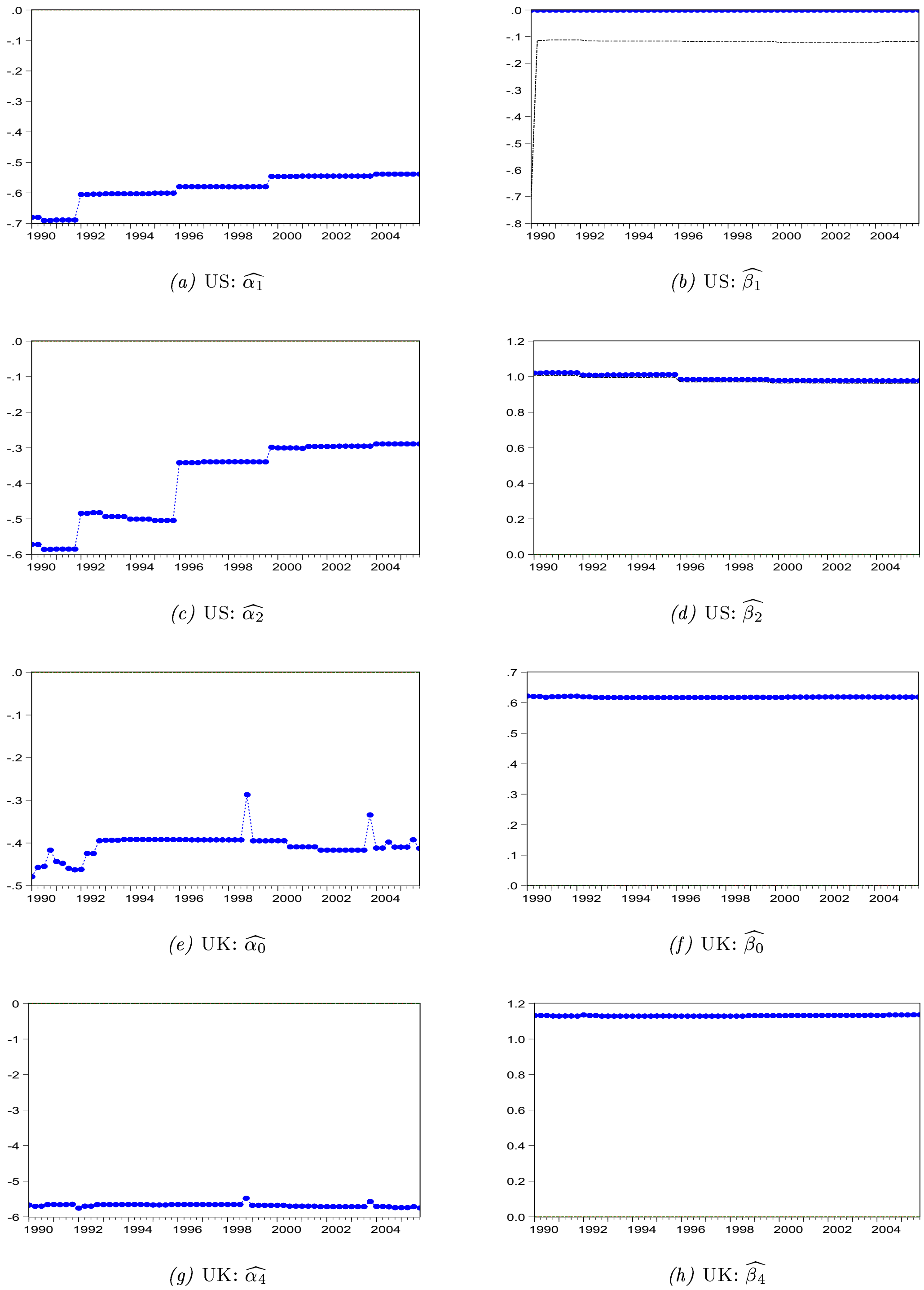
(a) US: $b - \widehat{b}$

(b) US: $\Delta_4 b - \widehat{\Delta_4 b}$

(c) UK: $b - \widehat{b}$

(d) UK: $\Delta_4 b - \widehat{\Delta_4 b}$

Figure 9: Revisions in the prediction errors ('disequilibria') for imports for the US and the UK based on their long-run relationships; cf. equation (9). Prediction errors for models estimated on data vintages marked 1973q1–2005q4 are measured relative to those estimated on the final vintage, 2005q4. Revisions in prediction errors corresponding to different vintages are distinguished by different symbols and shades. The horizontal axes present periods for the predicted values.



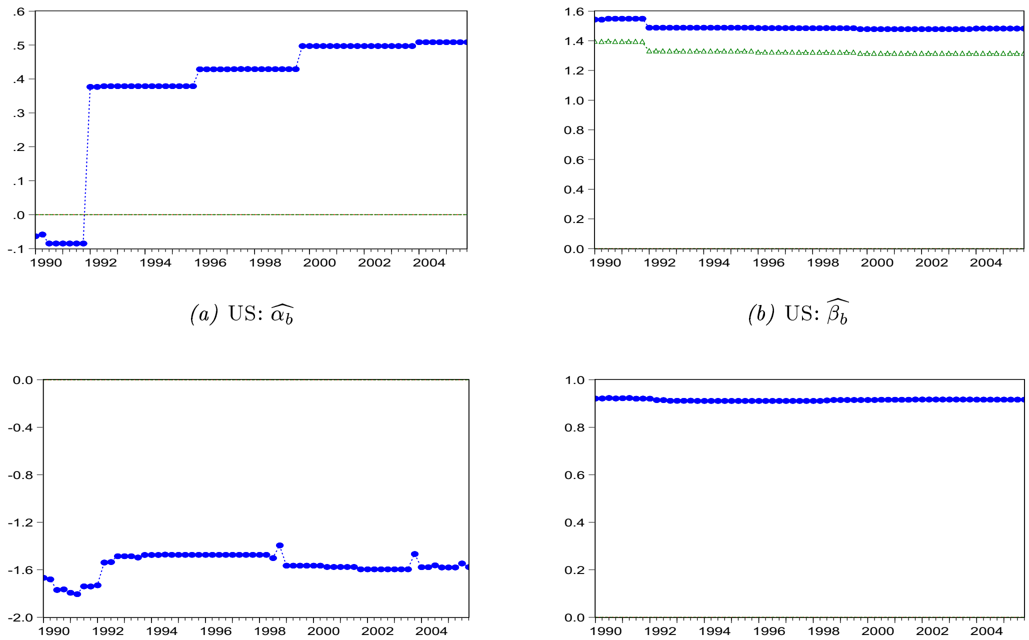
(a) US: $\widehat{\alpha_1}$ *(b)* US: $\widehat{\beta_1}$

(c) US: $\widehat{\alpha_2}$ *(d)* US: $\widehat{\beta_2}$

(e) UK: $\widehat{\alpha_0}$ *(f)* UK: $\widehat{\beta_0}$

(g) UK: $\widehat{\alpha_4}$ *(h)* UK: $\widehat{\beta_4}$

Figure 10: Fixed sample estimates of intercept terms and income elasticities of the US $m1$ and $m2$ aggregates based on data from different data vintages; see equation (2). Each dot represents an estimate based on a sample from a different data vintage, marked on the horizontal axes. The estimates are based on the same sample period, 1973q1–1989q4, for the vintages employed.



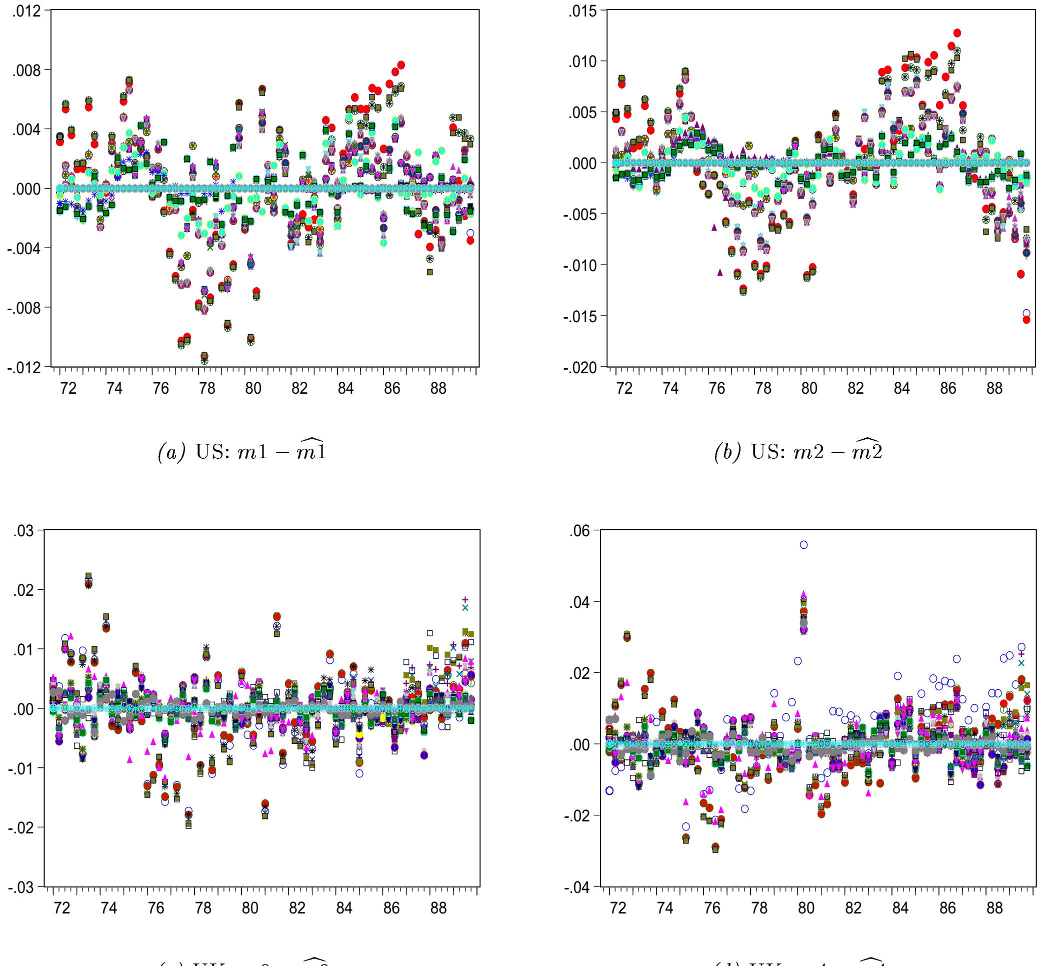
(a) US: $\widehat{\alpha_b}$

(b) US: $\widehat{\beta_b}$

(c) UK: $\widehat{\alpha_b}$

(d) UK: $\widehat{\beta_b}$

Figure 11: Fixed sample estimates of intercept terms and income elasticities of imports of the US and the UK based on data from different data vintages; cf. equation (3). Each dot represents an estimate based on a sample from a different data vintage, marked on the horizontal axes. The estimates are based on the same sample period, 1973q1–1989q4, for the vintages employed.



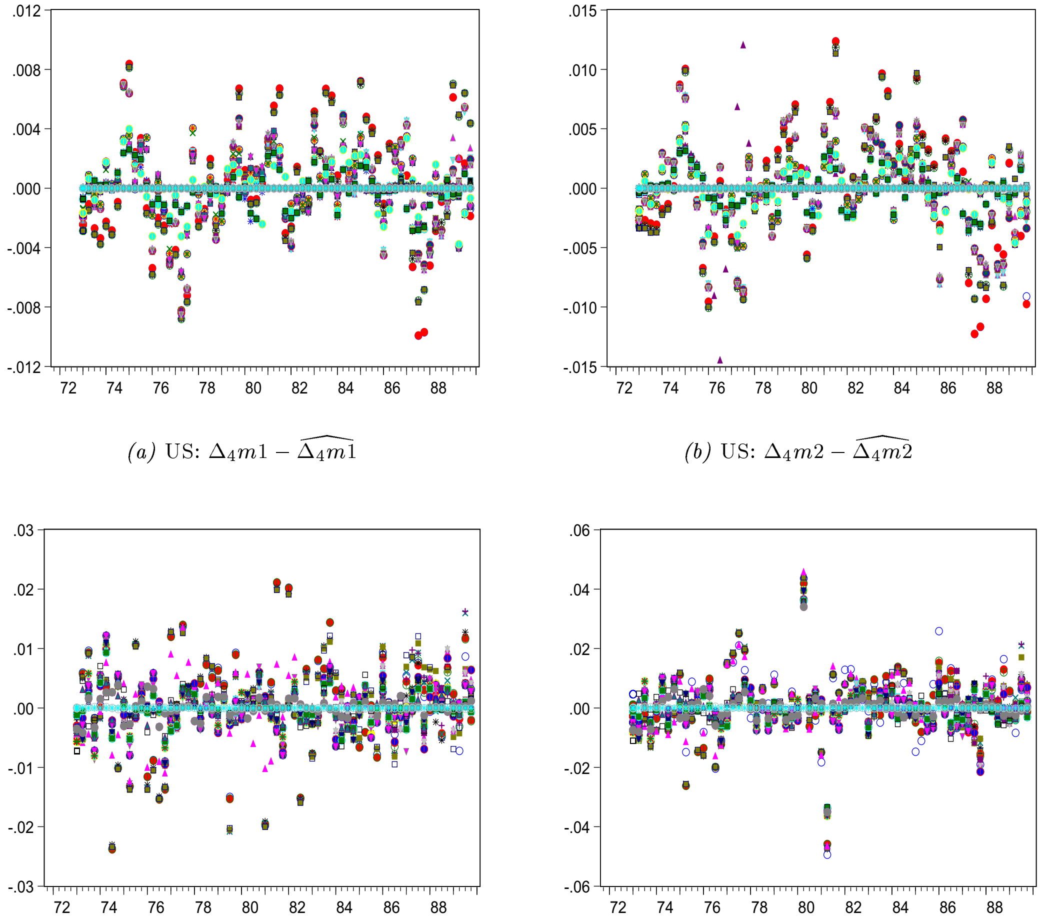
(a) US: $m1 - \widehat{m1}$

(b) US: $m2 - \widehat{m2}$

(c) UK: $m0 - \widehat{m0}$

(d) UK: $m4 - \widehat{m4}$

Figure 12: Revisions in the prediction errors ('disequilibria') for log values of monetary aggregates for the US and the UK based on their long-run relationships; cf. equation (7). Prediction errors for models estimated on data vintages marked 1973q1–2005q4 are measured relative to those estimated on the final vintage, 2005q4. Revisions in prediction errors corresponding to different vintages are distinguished by different symbols and shades. The horizontal axes present periods for the predicted values. The models have been estimated on fixed samples over the period 1973q1–1989q4.



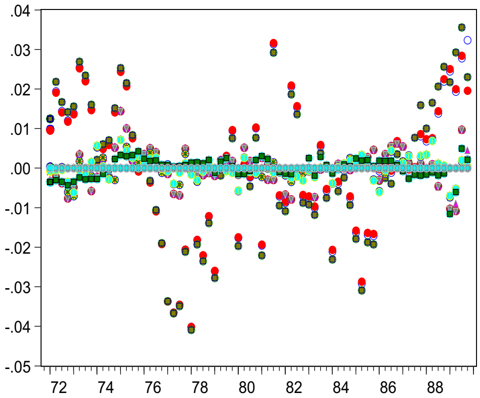
(a) US: $\Delta_4 m1 - \widehat{\Delta_4 m1}$

(b) US: $\Delta_4 m2 - \widehat{\Delta_4 m2}$

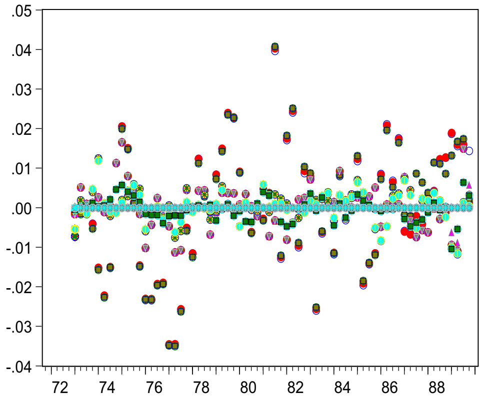
(c) UK: $\Delta_4 m0 - \widehat{\Delta_4 m0}$

(d) UK: $\Delta_4 m4 - \widehat{\Delta_4 m4}$

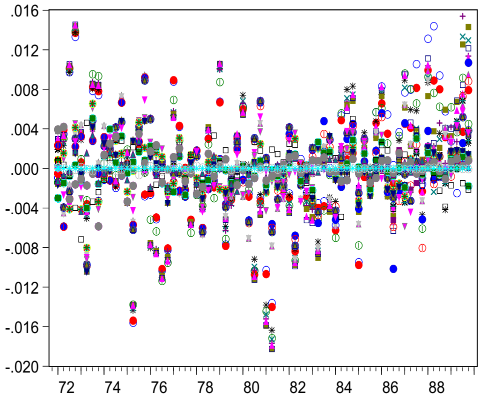
Figure 13: Revisions in the prediction errors ('disequilibria') for growth rates of monetary aggregates for the US and the UK based on their short-run relationships; cf. equation (8). Prediction errors for models estimated on data vintages marked 1973q1–2005q4 are measured relative to those estimated on the final vintage, 2005q4. Revisions in prediction errors corresponding to different vintages are distinguished by different symbols and shades. The horizontal axes present periods for the predicted values. The models have been estimated on fixed samples over the period 1973q1–1989q4.



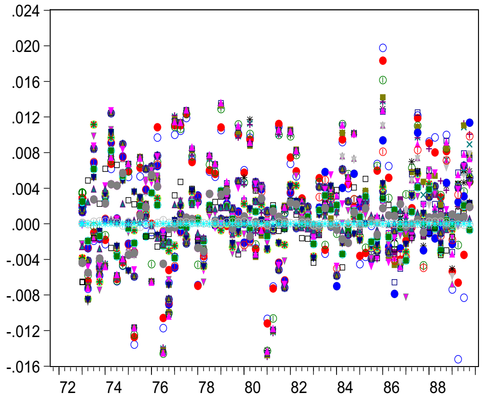
(a) US: $b - \widehat{b}$



(b) US: $\Delta_4 b - \widehat{\Delta_4 b}$

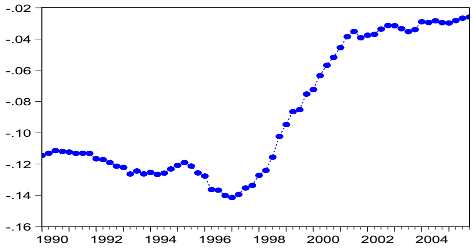


(c) UK: $b - \widehat{b}$

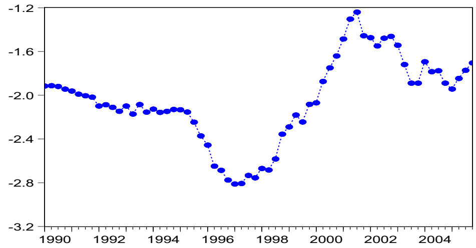


(d) UK: $\Delta_4 b - \widehat{\Delta_4 b}$

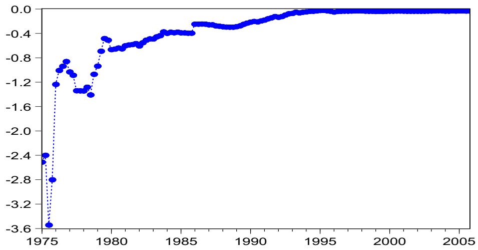
Figure 14: Left hand column: Revisions in the prediction errors ('disequilibria') for imports for the US and the UK based on their long-run relationships; cf. equation (9). Right hand column: Revisions in the prediction errors for growth rates of imports for the US and the UK based on their short-run relationships; cf. equation (10). Prediction errors for models estimated on data vintages marked 1973q1–2005q4 are measured relative to those estimated on the final vintage, 2005q4. Revisions in prediction errors corresponding to different vintages are distinguished by different symbols and shades. The horizontal axes present periods for the predicted values. The models have been estimated on fixed samples over the period 1973q1–1989q4.



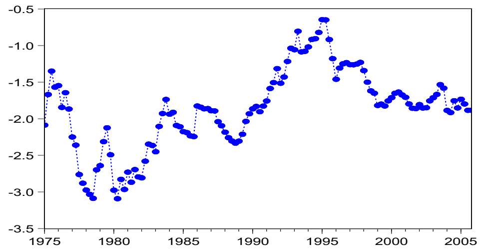
(a) US: $\widehat{\varrho_1}$



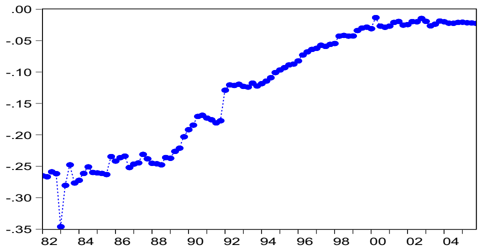
(b) US: $t_1 - ADF$



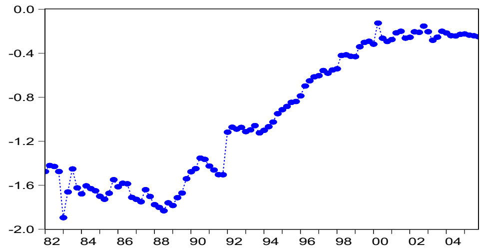
(c) US: $\widehat{\varrho_2}$



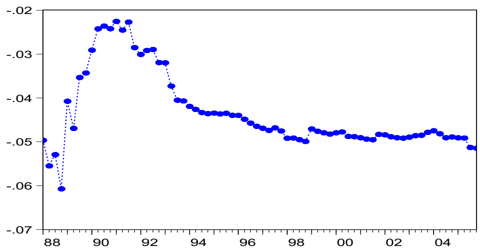
(d) US: $t_2 - ADF$



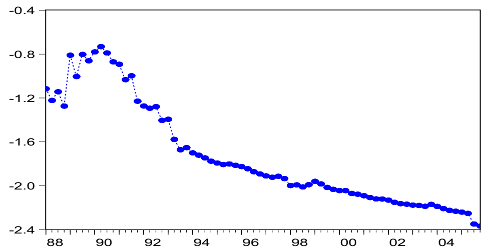
(e) UK: $\widehat{\varrho_0}$



(f) UK: $t_0 - ADF$

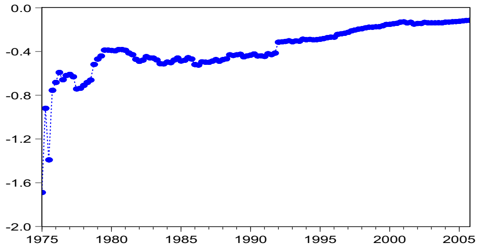


(g) UK: $\widehat{\varrho_4}$

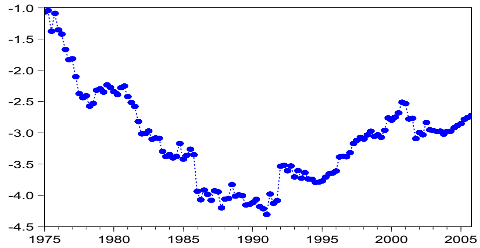


(h) UK: $t_4 - ADF$

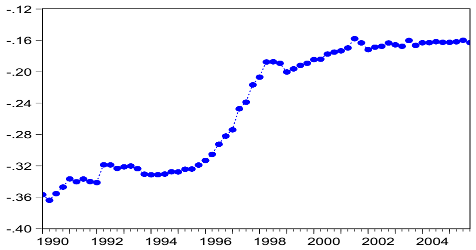
Figure 15: Cointegration tests for the US $m1$ and $m2$ relationships; cf. equation (11). Estimates of adjustment coefficient (in the left-hand column) and the corresponding t-ADF values using data from different vintages. Each dot represents an estimate based on a sample from a different data vintage, marked on the horizontal axes. The estimates are based on observations and sample periods that increase with the maturity of the vintages.



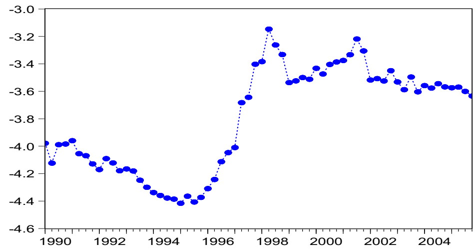
(a) US: $\widehat{\varrho}_b$



(b) US: $t - ADF$



(c) UK: $\widehat{\varrho}_b$



(d) UK: $t - ADF$

Figure 16: Cointegration tests for the import relationships for the US and the UK; cf. equation (11). Estimates of adjustment coefficient (in the left-hand column) and the corresponding t-ADF values using data from different vintages. Each dot represents an estimate based on a sample from a different data vintage, marked on the horizontal axes. The estimates are based on observations and sample periods that increase with the maturity of the vintages.

Policy analysis in real time using IMF's monetary model

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Research Department, Norges Bank

June 21, 2010

Abstract

We investigate to what extent estimated relationships of the IMF's monetary model and their policy implications are sample dependent. This model constitutes the core of the IMF's financial programming models for developing and emerging economies. We observe that estimates of the model's key parameters and model-based measures of macroeconomic disequilibria are highly dependent on data vintage employed. Changes in parameter estimates solely due to data revisions are found to be much smaller than those owing to parameter instability, which may be due to model misspecification. Moreover, instability in parameter estimates contributes to more uncertainty in evaluations of macroeconomic excesses than data revisions. It is shown that analyses based on a version of the model in difference form are more robust across data vintages than those based on the model with variables in levels. Well specified models that take into account known data revisions may also have relatively stable parameter estimates and hence more robust policy implications.

Keywords: *Real time data; Data and model uncertainty; IMF; Financial programming.*

JEL Codes: *C51, E41, E47, F17*

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1 Introduction

Information and due account of data revisions is important when drawing policy implications, as emphasized by recent research; see e.g. Orphanides (2001), Orphanides and van Norden (2002), Evans (1998) and Ghysels et al. (2002). It has been shown that apparently sound policy advice in real time can prove to be fallacious when evaluated in the light of revised data. So far, however, the literature on forecasting and policy analysis in the context of real time data has mostly, if not exclusively, focused on Taylor-type interest rate rules, Phillips curves and aggregate demand equations for industrialized countries. Little research has been conducted on the real time data implications for models used for policy analysis in developing and emerging economies.

This paper investigates how dependent policy analysis and evaluations based on the Polak model, also referred to as the IMF's monetary model, may be on data from different vintages; see Polak (1957, 1998). Specifically, we investigate how much estimates of key parameters of the Polak model and measures of economic disequilibria based on one data vintage change when data from a later data vintage is used. A 'vintage' refers to the data set available at a particular date, while 'real-time data' refers to a collection of such vintages. Later vintages contain more observations and cover longer sample periods than earlier vintages. In addition, later vintages may contain revised data relative to data from earlier vintages. In particular, we investigate the robustness of key parameter estimates and assessments of economic disequilibria to data revisions embedded in later data vintages. The paper sheds light on the scope for policy mistakes when the Polak model is used without adequate account of relevant country specific factors and data uncertainty.

The Polak model constitutes the foundation of the IMF's financial programming models, which are used to undertake policy analysis and offer policy advice to developing and emerging economies, especially those seeking IMF assistance; see e.g. Mikkelsen (1998), Mussa and Savastano (1999) and Rao and Nallari (2001, ch. 4). The policy advice often lays the foundation for short-run and medium-run policy actions aimed at correcting external imbalances and checking inflation. Such actions may be in terms of explicit or implicit quantitative targets for key variables including level or growth of public and private domestic credit, monetary aggregates, imports and nominal exchange rates. Sometimes, short-run and medium-run policy actions are part of long-run structural adjustment programs agreed upon between the IMF and assistance-seeking countries.

The model may also be used to evaluate macroeconomic performance in response to policy actions undertaken by governments receiving assistance from the IMF. Satisfactory macroeconomic performance as reflected in quantitative (intermediate) targets for key variables is often a prerequisite for the continuation of IMF assistance.[1,2] Evaluations of recent and likely future

[1] Polak (1991, p. 59) states that "The Fund's performance criteria have a precise meaning: unless they are met on the specified date, the next disbursement does not take place."

[2] A substantial number of IMF assistance programs have been revised and even suspended in response to large deviations from agreed-upon targets for key variables over the program period. For example, more than a third of all IMF support packages approved between 1973–1997 ended with disbursements of less than half of the initially

macroeconomic performance as well as of authorities' adjustment efforts are often conducted at quarterly intervals after the start of a program, which usually remains active for 1–3 years; see e.g. Polak (1991) and Mussa and Savastano (1999).

The Polak model has been quite influential for over a half century in policy analyses and evaluation; see Polak (1998), Mussa and Savastano (1999), Rao and Nallari (2001, ch. 4), Rowe (2008) and Boughton (2004). One of the advantages of the Polak model is its parsimony, which facilitates its communication, estimation and application to different countries with minor adjustments; see e.g. Polak (1998). This is especially important because high quality data may not be available for many developing and emerging economies for development of large and complex models and precise estimation of model parameters; see Polak (1991).

Financial or stabilization programs based partly on some version of the Polak model are not derived mechanically but also rely on considerable judgement to take into account a country's economic and political situation; see Mussa and Savastano (1999) and Polak (1991, 1998). Moreover, policy recommendations are reached in an iterative fashion over time in response to more information and changes in a country's circumstances and future prospects.

Still, the design and evaluation of economic adjustment programs seem to be vulnerable to data revisions. This is because economic adjustment programs are designed and evaluated using the latest estimates of the country's main economic variables and their short-term projections; see Mussa and Savastano (1999). The latest data, though important for policy analysis, are not necessarily accurate since, in general, there is a tradeoff between timeliness and accuracy of data.

Previously, a number of studies including Reinhart (1990) and Easterly (2006) have pointed out instability in parameter estimates of the Polak model due to structural changes and/or its possible misspecification. Potential changes in estimates of key parameters over time and across countries are also acknowledged by users of the Polak model embedded in financial programming models; see e.g. Khan et al. (1990), Mussa and Savastano (1999) and Polak (1998). However, it is assumed that the iterative nature of the financial programming approach and practitioners' willingness to amend the behavioral equations and adjust parameter estimates in the light of any available information may safeguard against policy errors. Moreover, it is assumed that it is sufficient for parameter estimates to be stable over the relatively short horizon of an economic adjustment program; see e.g. Khan et al. (1990) and Mussa and Savastano (1999).[3]

Our study may be considered an extension of earlier studies. It does not only examine possible changes in parameters and policy implications over time and across countries, but also across differ-

agreed support; see Mussa and Savastano (1999).

[3]For example, Khan et al. (1990) state that "While experience would lead one to reject the extreme view that the income velocity of money is constant, This does not materially affect the analysis. All that is needed in this framework is that the demand for money, or velocity, respond in a predictable fashion over the program period to changes in variables such as real income and prices..." However, our analysis implies that predictability based on a given data sample (vintage) may not be robust to data revisions.

ent data vintages for a given time period and country.[4] Moreover, it sheds light on to what extent the iterative nature of the financial programming approach and practitioners' use of judgement may help safeguard against policy errors. In particular, whether one is justified in assuming that its parameter estimates can be considered stable over the relatively short horizon of an economic adjustment program.

The limited availability of high quality data for developing and emerging economies makes it difficult, if not impossible, to examine policy advice in real time with the hindsight of mature data, which are the outcome of one or several revision rounds. Nevertheless, given the influence of the Polak model in policy formulation and evaluation of macroeconomic performance, it is important to shed light on how sensitive the model's key parameters and policy implications could be to data revisions. The model's key equations depend on a series that often undergoes the heaviest data revisions, namely GDP; cf. Croushore and Stark (2001) and Orphanides and van Norden (2002).

We employ real time data for the US and the UK to shed light on the issue. We conjecture that data and estimates of key parameters for developing and emerging economies are likely to be at least as sensitive to shifts in data vintages as those for the US, the UK and other industrialized countries.[5] These countries have more experience and better infrastructure for the compilation and processing of economic data than most of the developing and emerging economies. Yet, for example for US GDP, Croushore and Stark (2001) note that real GDP growth numbers have undergone substantial revisions even twenty years after their first release; the revisions have been within the range –5.5 to 8.5%.

Our findings support earlier studies pointing out instability in the parameter estimates over time and cross-country differences. Moreover, we find that measurement errors, as revealed by subsequent data revisions over many years, introduce substantial uncertainty about values of key variables and parameter estimates of a model, even for a given country and a given time period. Accordingly, one may not obtain relatively precise values of key macroeconomic variables, parameter estimates and forecasts until after several years. It is also found that revisions in variables may lead to substantial revisions in macroeconomic assessments in spite of stable parameter estimates. The latter finding suggests limitations on what a model builder can do to reduce the scope for policy errors, but supports the use of information in addition to that embedded in the model and data sample as well as the use of decision frameworks that explicitly acknowledge nonquantifiable data and/or model uncertainty; cf. Hansen and Sargent (2007).

It is important to clarify at the outset that we are not able to evaluate actual applications of financial programming models given the extensive use of judgement in the formulation and evalu-

[4] Easterly (2006), examining both the identities as well as the behavioral equations of the Polak model, has pointed out large statistical discrepancies in the accounting identities used in the model and that econometric estimates of key parameters often deviate significantly from their assumed values. Moreover, the estimates have been shown to differ notably across countries.

[5] We have also undertaken the investigation using real time for Norway. The results, available on request, were found to be comparable with those for the US and/or the UK.

ation of financial programs and the lack of real time data for developing and emerging economies. Our analysis is also limited as it only examines parts of a financial programming model, which would typically contain a large number of behavioral equations and accounting identities in addition to some versions of the behavioral equations of the Polak model. Furthermore, the analysis should not be considered a critique of the Polak model per se, as challenges posed by data subject to revisions would also be posed by any policy and forecasting model based on such data.

The remaining paper is organized as follows. In the next section, we present key behavioral relationships and parameters of the Polak model. Section 3 and Appendix 6 briefly present the quarterly real time data sets for the US and the UK and show the degree to which the data are affected by revisions. Section 4 presents our empirical analysis based on these real time data sets while Section 5 investigates the contribution of data revisions to our results. Section 6 concludes.

2 The Polak model: relationships and key parameters

The core stripped-down version of the Polak model consists of two behavioral equations. One behavioral equation is based on the quantity theory, characterizing the relationship between money, nominal GDP and the money velocity parameter. The other behavioral equation is a linear relationship between aggregate imports and nominal GDP, where the elasticity of imports with respect to nominal income is the key parameter. The core model version also includes two identities: the balance of payment identity and the monetary survey identity, which states that aggregate money equals net domestic credit and net foreign exchange reserves; see e.g. Khan et al. (1990) and Polak (1998). This study focuses on the behavioral equations, while the identities are the main subject of Easterly (2006).

In model applications, the velocity of money (V) may be inferred by taking the ratio of nominal GDP to a monetary aggregate:

$$V = PY/M, \tag{1}$$

where PY denotes nominal GDP, while M is a monetary aggregate, e.g. *M1* or *M2*. This relationship assumes income elasticity of money demand to be unity. Target values of monetary aggregates may be derived from such identities conditional on an estimate of velocity and some target values or projections of nominal income. Alternatively, one may calculate values of velocity using forecasts of money demand and nominal income to cross check their reasonability in the light of velocity values obtained. For simplicity, one may also set expected value of future velocity to its observed value at the end of the sample period, or equal to a sample average of its observed values; see e.g. Reinhart (1990).

The second key parameter is the income elasticity of imports, which follows from the assumption of a linear relationship between aggregate imports (B) and nominal GDP. The income elasticity of imports is often assumed to be one, or inferred by taking the ratio between imports and nominal GDP. Future values of the income elasticity of imports can be projected using techniques similar to that used for money velocity.

Estimates of income elasticities play a key role in projections of future money demand and imports. Thereby they also affect (e.g. ceilings on) the level of credit to the government and/or the private sector as well as foreign exchange rate policies aimed at achieving (e.g. some minimum level of) foreign reserves to pay for projected imports. For example, import projections may be used to infer the required devaluation of a currency to achieve external balance.[6]

We base our main analysis on (log) linear money demand and import functions where the assumption of unit elasticities of money and imports with respect to income may be relaxed. Such models are commonly used and have been formulated in (log) levels of the variables or in difference terms in the relevant literature; see e.g. Burth and Chadha (1989), Khan et al. (1990), Reinhart (1990), Mikkelsen (1998), Polak (1998) and Easterly (2006).

We consider the following static long-run relationships between money and nominal income and between imports and nominal income:

$$mi_t^v = \alpha_i + \beta_i py_t^v + \epsilon_{i,t}^v, \tag{2}$$

$$b_t^v = \alpha_b + \beta_b py_t^v + \epsilon_{b,t}^v, \tag{3}$$

where small letters indicate the corresponding variables in logs. The Greek letters α_i and α_b are intercept terms; β_i and β_b are the income elasticities of a monetary aggregate mi (e.g. $m0$, $m1$ and $m2$) and imports, respectively; while $\epsilon_{i,t}^v$ and $\epsilon_{b,t}^v$ are error terms. It follows that one may interpret $\epsilon_{i,t}^v$ as representing deviations from expected money velocity; cf. IMF (2004, p. 31). Superscript v and subscript t denote vintage and time period, respectively. The parameters, αs and βs, are assumed to be constant over time.

We examine variation in parameter estimates across different vintages and the validity of the posited long-run relationships, (2) and (3), by testing whether they can be considered cointegrating relationships based on data from different data vintages. It is commonly assumed that nominal GDP, money balances and imports are non-stationary integrated variables. We employ the two-step procedure of Engle and Granger (1987) to test for cointegration. Such an exercise may also shed light on previous studies of money and import demand using data from different vintages.

We also consider the models in difference form:

[6] This study is also relevant for the related literature on fundamental equilibrium real exchange rates. Models of fundamental equilibrium real exchange rates are often based on estimated trade equations; see MacDonald and Stein (1999) and the references therein. Information about the extent of revisions in domestic and foreign GDP and income elasticities of imports and exports may be helpful in assessing the data uncertainty associated with measures of real exchange rate misalignments.

$$\Delta_4 mi_t^v = \gamma_i \Delta_4 py_t^v + \varepsilon_{i,t}^v, \quad (4)$$

$$\Delta_4 b_t^v = \gamma_b \Delta_4 py_t^v + \varepsilon_{b,t}^v, \quad (5)$$

where Δ_4 is the 4th difference operator while $\varepsilon_{i,t}^v$ and $\varepsilon_{b,t}^v$ are error terms. We choose the fourth difference because our data is quarterly and it is easier to relate to per annum growth rates. The slope coefficients, γs, in these models can be interpreted as short-run elasticities of money and imports to income. It has been argued that such models with (constant) short-run point elasticities may be, or would have to be, relied upon to forecast variables of interest over relatively short horizons; cf. Mussa and Savastano (1999).[7]

In applications of the Polak model to developing countries with small and shallow credit markets, interest rates are not usually included in the money demand equations; see e.g. Polak (1998) and Mikkelsen (1998). And, for countries with fixed exchange rate regimes, exchange rates are not explicitly included in the import equations; see e.g. Khan et al. (1990) and Easterly (2006). Some studies, however, extend the simple version of the model with nominal interest rates and exchange rates; see e.g. Polak and Argy (1971), IMF (2004) and Mikkelsen (1998).

We control for possible effects of interest rates on money demand as well as money velocity by including nominal interest rates in the money demand equations (2) and (4). We also control for possible effects of exchange rates on imports by including nominal effective exchange rates in the import equations, (3) and (5), when estimating them.[8]

A priori, it is not possible to say whether analysis based on equations with variables in the difference form would be more robust to data revisions than those based on variables in the level form. On the one hand, revisions in levels of variables may be larger than revisions in their growth rates. A definitional change may show up as a persistent error in the level of e.g. GDP, money stock and imports, while it need not show up as an error in their growth rates; cf. Mankiw et al. (1984). If such persistent errors are not accounted for, they may lead to omitted-variable bias in parameter estimates. Therefore, modeling the rate of money and import growth rather than their levels may reduce the problem caused by redefinitions. For example, Howrey (1996) shows that forecasts of the level of GNP are much more sensitive to data revisions than forecasts of growth rates.

[7] Mussa and Savastano (1999) note "...there is no escape from assuming some degree of predictability of the demand for money, in accord with some quantifiable model. In particular, the numerical quasi ceiling for base money will require judgement about how the demand for money will behave over the coming two to four quarters. This involves, at least implicitly numerical values for the short-run point elasticities of money demand."

[8] Our conclusions are robust to the use of more general dynamic models for money and imports. Some studies employ dynamic versions of the models in log levels or in difference forms including several lags of the right-hand side and left-hand side variables in the equations (2)–(5). In particular, equilibrium correction models (ECMs) of money demand and import growth have been employed to explicitly embed long-run relationships in their dynamic models; see e.g. Mikkelsen (1998) and Qin et al. (2005). The ECM representation presupposes cointegration between the variables defining the long-run relationships.

On the other hand, equations with variables in levels estimated by OLS may be more robust to data revisions than those with variables in the difference form because of the super-consistency property of OLS estimators in the former case, especially if the measurement errors are stationary; c.f. Engle and Granger (1987). One may consider preliminary data releases to suffer from measurement errors relative to the corresponding final estimates or the "true" value of the variables. Thus, preliminary data releases of variables may be characterized as measured with classic errors-in-variables; c.f. Maravall and Pierce (1986). Such measurement errors may not only lead to omitted variable bias but also to simultaneity bias in OLS estimates of parameters by contributing to correlation between the error terms and the right-hand side variable(s). However, if the variables in the equations are cointegrated, OLS estimators would be super-consistent and diminish possible bias due to measurement errors. The super-consistency property would also diminish simultaneity bias that may arise because of the possible endogeneity of right-hand side variables including nominal GDP, which may be determined simultaneously with money and imports.

However, the super-consistency property of OLS estimators may not be strong in small samples; see e.g. Banerjee et al. (1993). Therefore, omitted-variable bias due to level shifts that are not accounted for and possible simultaneity bias due to measurement errors and right-hand side endogenous variables may not be negligible. To test the sensitivity of OLS parameter estimates to possible simultaneity bias, we employ the instrumental variable (IV) method to estimate the parameters of the models in levels as in difference forms. We estimate the models with the IV method using lagged values of e.g. nominal GDP from earlier vintages. This is based on the assumption that lagged values of e.g. nominal GDP level and growth are likely to be correlated with current dated values from later vintages, while measurement errors in lagged values from one vintage may not be correlated with measurement errors in future values of GDP from a later vintage.

2.1 Revisions in data and measures of macroeconomic disequilibria

To assess possible effects of data revisions on parameter estimates and the model's predictions of key variables, we assume the final vintage in our real time data sets to contain the "true" observations of the variables, in line with common practice; see e.g. Croushore and Stark (2001). Hence, the parameter estimates and model's predictions based on the final vintage (fv) can be considered as our reference values. The vintage of 2005q4 is the final vintage in our data sets.

We measure revisions in data from a vintage v relative to the data from the final vintage, fv, as:

$$rev\_X_t^v = X_t^v / X_t^{fv} - 1, \tag{6}$$

where $rev\_X_t^v$ denotes revision in the value of a variable X in period t from vintage v, X_t^v, relative to that from the final vintage, X_t^{fv}.

Measures of excess money and imports may be used as indicators for the prudence of monetary and fiscal policies and to evaluate macroeconomic performance in response to policy actions implied by an economic adjustment program and the authorities' adjustment efforts. Performance criteria are typically specified as quarterly ceilings on the expansion of net domestic credit of the central bank and as quarterly floors on net international reserves. They may also be specified as the desired path for monetary aggregates and imports; see e.g. IMF (2004, p. 19).

Excess money level or money growth can be defined as: $mi_t^v - \widehat{mi}_t^v$ and $\Delta_4 mi_t^v - \Delta_4\widehat{mi}_t^v$, respectively. Here, $\widehat{mi}_t^v$ and $\Delta_4\widehat{mi}_t^v$ denote the money level and money growth predicted by estimated versions of equations (2) and (4), respectively. The gaps $mi_t^v - \widehat{mi}_t^v$ and $\Delta_4 mi_t^v - \Delta_4\widehat{mi}_t^v$ are (technically) mispredictions of money level and money growth, respectively. Similarly, excess import level and growth can be defined as $b_t^v - \widehat{b}_t^v$ and $\Delta_4 b_t^v - \Delta_4\widehat{b}_t^v$, respectively, where $\widehat{b}_t^v$ and $\Delta_4\widehat{b}_t^v$ denote import level and import growth based on estimated version of equations (3) and (5). Variables with "$\widehat{\text{s}}$" are model-consistent values of the corresponding macroeconomic variables.

Money stock or money growth differing (sizably) from the predicted level or from growth in money demand may be considered inconsistent with targets for inflation, domestic credit growth and net international reserves; see e.g. Mussa and Savastano (1999). Especially, a high level of import or import growth may make it difficult to maintain net international reserves above their specified floor level and hence be considered inconsistent with the desired path of international reserves over time. On the other hand, a lower level or growth in actual imports relative to corresponding values of predicted imports may lead to higher international reserves than targeted and thereby to a rise in money stock. It has been observed quite frequently that targets for e.g. broad money growth are overshot by wide margins often due to larger-than-expected increases in foreign assets; see e.g. Schadler (1996). A lower level or growth in actual imports than corresponding values of predicted imports can also be interpreted as an indication of structural impediments to the flow of imports, warranting changes in foreign trade policies.

Measures of excess money and imports, which are (technically) in-sample prediction errors, may also be considered indicators of the forecasting properties of their models. Money demand and import demand equations provide essential input to the process of designing and evaluating economic adjustment programs. For example, to set ceilings on domestic credit growth, an estimated money demand equation may be used to derive a reasonable path for a monetary aggregate under a program's assumptions regarding e.g. output growth and inflation. The ceiling on domestic growth may then be obtained by subtracting the floor on net international reserves from the desired path of the monetary aggregate; see e.g. Mussa and Savastano (1999).

Forecasts based on the behavioral equations are also used as reference values to cross check derived values of money and imports from the accounting identities, conditional on provided values for the remaining variables in the macroeconomic identities; see e.g. Easterly (2006). For example, if there is a deviation between the derived value of imports from the balance of payment identity, conditional on e.g. a preferred path for international reserves and assumed exports, assumptions about exports and/or capital flows may need to be reconsidered to make the derived import figures consistent with the predictions for demand for imports at the projected levels of output and prices.

Given that prediction errors may be useful statistics for diagnosing macroeconomic issues as well as econometric issues related to model specification, it is important to investigate how robust they would be to data revisions. To examine revisions in the (in-sample) prediction errors, alternatively in measures of excess money level and money growth, we report differences in money level and money growth gaps, from a vintage v to those from the final vintage (fv):

$$rev\_mi_t^v = (mi_t^v - \widehat{mi}_t^v) - (mi_t^{fv} - \widehat{mi}_t^{fv}). \tag{7}$$

$$rev\_\Delta_4 mi_t^v = (\Delta_4 mi_t^v - \Delta_4\widehat{mi}_t^v) - (\Delta_4 mi_t^{fv} - \Delta_4\widehat{mi}_t^{fv}). \tag{8}$$

As the disequilibrium from the estimated long-run relationship for money may be interpreted as money velocity, $rev\_mi_t^v$ may be considered revisions in money velocity while $rev\_\Delta_4 mi_t^v$ may be interpreted as revisions in velocity growth.

Revisions in excess import level and import growth are defined as the corresponding terms for money stocks; see equations (7)–(8). Specifically,

$$rev\_b_t^v = (b_t^v - \widehat{b}_t^v) - (b_t^{fv} - \widehat{b}_t^{fv}), \tag{9}$$

$$rev\_\Delta_4 b_t^v = (\Delta_4 b_t^v - \Delta_4\widehat{b}_t^v) - (\Delta_4 b_t^{fv} - \Delta_4\widehat{b}_t^{fv}), \tag{10}$$

where $(b_t^v - \widehat{b}_t^v)$ and $(\Delta_4 b_t^v - \Delta_4\widehat{b}_t^v)$ represent import level and growth in excess of the predicted values implied by the estimated versions of their models: (3) and (5).

3 Real time data

The following subsections briefly present the quarterly real time data sets for the US and the UK used in our empirical analysis. It is shown that the variables considered, including monetary aggregates, undergo sizable revisions over time which tend to decline with the maturity of vintages. It is also shown that there is no general pattern in data revisions in real time data sets for the two countries examined. The pattern and size of revisions differ across countries and time series of variables considered.

3.1 The US

For the US, we have obtained seasonally adjusted data for nominal GDP (PY), nominal imports (B) and monetary aggregates ($M1$ and $M2$) from the Federal Reserve Bank of Philadelphia.[9] The data is quarterly for nominal GDP and imports but monthly for $M1$ and $M2$. We let monthly observations for the middle month in a quarter represent quarterly observations, in line with common practice. The data included in each vintage are those an economic analyst would have in the middle of each quarter. Thus the vintages correspond to data as they existed on e.g. November 15 1977, February 15, 1978, and so on. The US data set is well known and has been previously employed in a number of studies including Orphanides (2001), Orphanides and van Norden (2002), Clark and McCracken (2009) and the references therein. We refer to Croushore and Stark (2001) for more information about the different data vintages.

We use data vintages that were available in 1973q1, 1973q2, 1973q3,...2005q4. Each of the data vintage v, marked 1973q1, 1973q2,...,2005q4, contains time series of the relevant macroeconomic variables over the period 1972q4 to $v - 1q$, as there is a one-quarter publication lag for the first releases of the data. For example, the data vintage marked 1977q3 would contain observations for the period 1972q4–1977q2.

[Figure 1 about here.]

Figure 1 gives an impression of data revisions in US nominal GDP (PY), imports (B), $M1$ and $M2$. The figure presents their values from every vintage considered, 1973q1–2005q4, relative to the corresponding values from their final vintage: 2005q4. In precise terms, it shows values of $rev\_X_t^v$ which is defined in (6), where $X = PY$, B, $M1$ and $M2$. At each point in time there are z observations for every X which decline by one for every quarter as we go forward in time. That is, $z =$ Total vintages - p, where $p = 1, 2,...T$ indicates the period number. Thus, for period 1973q1 there would be 132 observations of X, while for period 2005q3 there would be just one observation of X, contained in the data vintage marked 2005q4.

Figure 1 shows that revisions in the US data can be substantial. Figures 1.a–b show that observations for PY and B from some vintages differ substantially from their final releases. In general, the extent of revisions for a particular period declines over time as the observations "mature", i.e. come from later vintages. In percentage terms, the nominal GDP revisions vary in the −11 to 2%, while those for imports vary in the −5 to 16%. Negative values imply underestimation relative to values from the final vintage. Accordingly, values of nominal GDP seem to have been mostly underestimated in earlier data vintages relative to the values in the final vintage. In contrast, import values seem to have been mostly overestimated in earlier vintages relative to the values in the final vintage. In the case of US GDP, we observe that contents of vintages tend to

[9] The data set can be downloaded from www.phil.frb.org/econ/forecast/reaindex.html.

converge towards that of the final vintage; earlier vintages differ more from the final vintage than later vintages. This is, however, not the case for US imports.

Figures 1.*c* suggests that revisions in *M1* are not negligible, being within the range –1 to 4%. Revisions in *M2* are mostly comparable to those in *M1* in size; see Figure 1.*d*. The exception is the vintages marked about 1978. The positive values of *M2* revisions from the early 1980s and mid-1990s vintages suggest that they overestimated money stock relative to the later vintages.

It follows that estimates of money velocity, which is a key parameter of the Polak model, are subject to substantial revisions. Values of *M1* velocity (*V1*) mostly reflect revisions in nominal GDP. This is also the case for the values of *M2* velocity (*V2*), except for the vintage marked 1978; see Figures 1.*e–f*. The figures show that revisions in velocity are in the –14 to 3% in the case of *V1* and in the range –10 to 1% in the case of *V2*, except for the values implied by the 1978 vintage. We also note that velocity values derived from earlier vintages have tended to underestimate the velocities relative to those based on the final vintages.

3.2 The UK

For the UK, we employ seasonally adjusted quarterly data for real GDP (Y), the GDP deflator (P), $M0$, $M4$ and nominal imports (B). The series have been compiled by Garratt and Vahey (2006) except for nominal imports, which were initially compiled by Castle and Ellis (2002) but are updated and made available by the Bank of England.[10] The UK real time data is not as extensive as the US data. Real time observations for *M1* and *M2* are not readily available, while only a limited number of vintages are available for *M3*.

We use data vintages marked 1982q1, 1982q2, 1982q3,...2005q4. A data vintage v contains time series for the variables over the period 1973q1 to $v - 2q$, as there is a two-quarter publication lag for the first releases of the data.

[Figure 2 about here.]

Figure 2 provides an impression of the extent of data revisions in UK nominal GDP (PY), imports (B), $M0$ and $M4$; PY denotes the product of the real GDP series and the deflator. The figures show revisions in these variables relative to the final vintage (2005q4) over the period 1973q1–2005q2. Here, $rev\_X_t^v$ is defined by equation (6) for the case of the UK PY, B, $M0$ and $M4$.

Figure 2.*a* shows that the data revisions in the case of nominal GDP are in the range –20 to 3%. In particular, two of the data vintages from the late 1990s and early 2000s heavily underestimate nominal GDP relative to the final vintage. For the other vintages, the revisions remain mostly within the range –4 to 3%. Revisions in import figures are relatively small for the years up to the

[10]The import data has been downloaded from http://www.bankofengland.co.uk/statistics/gdpdatabase. The other series for the UK have been kindly provided by Shaun Vahey on request.

late 1980s, mostly within the range –0.5 to 1%; see Figure 2.*b*. Afterwards, however, the revisions are as large as –8% relative to the data points from the final vintage. Notably, the size of revisions, which in this case are underestimations relative to the final data points, seems to increase from the early 1990s to early 2000s.

Revisions in monetary aggregates are also sizeable, especially those in $M0$. Revisions in the UK $M0$ are mainly within the range –6 to 2% and mostly comparable to those for the US $M1$ in absolute terms; see Figure 2.*c*. The range of revisions in the UK $M4$ is somewhat smaller with most of the revisions occurring in vintages from the 1980s onwards; see Figure 2.*d*. In particular, large revisions are not confined to a few vintages and do not display any systematic trend as they do in the case of the US $M2$.

Values of *M0* velocity and *M4* velocity, *V0* and V4, respectively, undergo revisions in the range −20 to 5% and –18 to 3%, respectively; see Figures 2.*e*–*f*. However, most of the revisions are within the range –5 to 5% and –5 to 3%, respectively. Except for underestimation of the velocities by some data vintages, the revisions seem to be symmetric relative to velocity values based on data from the final vintage.

4 Policy analysis in real time

This section sheds further light on uncertainty in parameter estimates and policy analysis when they are based on all available observations of variables from the latest vintage at each point in time.[11] We estimate the models on all data from (almost) all available vintages for both of the countries. The start periods of the samples are kept fixed while the number of observations, and hence the length of sample periods, increases with the maturity of data vintages. We neglect some initial vintages in each of the real time data sets to obtain a sufficient number of observations for the estimation of parameters.

4.1 Shifts in estimates of long-run parameters

We first present estimates of intercepts terms and slope coefficients, which represent income elasticities of money demand and import demand; see equations (2)–(5). The estimates are based on equations where we have controlled for the effects of (nominal) interest rates and nominal effective exchange rates. The results would not have differed much if we had not controlled for the effects of these variables, which is not uncommon in applications of the Polak model.

Figure 3 suggests that estimates of intercept terms and slope coefficients in the money demand equations differ substantially across data vintages for the two countries. Overall, estimates of the

[11] For example, a hypothetical researcher conducting research in 1990q1 bases his/her analysis on the data from the vintage marked 1990q1 and extracts data for the period 1973q1 to 1989q1. When conducting the research in 1997q4, the researcher bases the analysis on the vintage marked 1997q4 and extracts data for the period 1973q1–1997q3 and so on.

intercept terms in the money demand equations are relatively more vulnerable than estimates of slope coefficients to changes in data vintages. For the US, the estimated intercept term in the $m1$ equation varies in the range –0.8 to 1.5, while the corresponding slope coefficient estimates vary in the range 0.6 to 0.9; see the top panel of Figure 3. In the case of the US $m2$ equation, estimates of the intercept term vary in the range –2 to 0.3 while the corresponding slope coefficient estimates vary in the range 0.9 to 1.17. In the case of the UK $m0$, the slope coefficient displays an inverse v-shape, which is also reflected in the corresponding intercept estimate. The slope coefficient varies in the range 0.62 to 0.72, while the intercept terms vary in the range –1.8 to –0.3. In the case of the UK $m4$, the intercept estimate changes (gradually) from –5 to –7, while the slope coefficient estimate changes from 1.07 to 1.22 when the sample varies with the vintage.

[Figure 3 about here.]

The results for all of the import demand equations but one suggest relatively small variation in estimates of slope coefficients across vintages; see the right column of Figure 4. The exception is the case of US imports where the slope coefficient estimates vary from about 3.5 to 1.5. However, there is relatively little variation in the estimates of this slope coefficient in the vintages from 1990s onwards. In contrast, estimates of the intercept terms display relatively large variation across data vintages; see the left column of Figure 4.

[Figure 4 about here.]

The magnitude of shifts in parameter estimates across data vintages were about the same when equations (2)–(5) were estimated by the instrument variable (IV) method, even though the IV parameter estimates did differ slightly from the corresponding OLS estimates; see e.g. 10.b and 11.b. For brevity, we therefore do not display all IV estimates of the parameters.

We have also tested whether money demand and import equations for the US and the UK constitute statistically valid long-run, or cointegrating, relationships across different data vintages. Further details and results are presented in Appendix B.

In sum, the support for cointegration between the relevant variables in money demand equations has been found to be weak, if present at all, and highly dependent on data vintage and sample. The import demand equations have been supported in data across nearly all data vintages. The strength of the support for cointegration is, however, vintage-dependent. Moreover, there is relatively large variation in the corresponding estimates of the adjustment coefficients across data vintages suggesting a widely different speed of adjustment of actual imports to their model-based equilibrium values. In the case of US imports, estimates of the adjustment coefficient (mostly) vary in the range (–0.90, –0.1) while those for the UK imports vary in the range (–0.37, –0.15).

4.2 Shifts in estimates of short-run parameters

In the following, we estimate money demand and import demand equations in difference terms, assuming the differenced variables are stationary; see equations (4) and (5). Models in difference forms may be employed when cointegration between the variables in level is not supported, as in the case of the long-run money demand equations considered above.

The analysis sheds lights on to what extent models in difference forms are less susceptible to changes in data samples than models in levels. Variables (entering models) in difference terms such as growth rates often undergo smaller data revisions than variables in levels that may experience level shifts due to data revisions. Such level shifts in variables may have considerable effects on estimates of intercepts, in particular, as observed in the case of the long-run money demand and import equations. The super-consistency property of the OLS estimator when the variables in levels are cointegrated could still have contributed to weakening the effect of data revisions on the parameter estimates, particularly the slope coefficients, which were found to be relatively stable. Such an effect would not be present when we estimate models in difference form representing relationships between stationary variables.

[Figure 5 about here.]

[Figure 6 about here.]

Figures 5 and 6 present estimates of the income elasticity of money demand and imports using the equations in difference form. The results suggest that estimates of the slope coefficients, representing short-run income elasticities of money and import demands, vary in about the same range when the models are estimated in difference forms as when they are estimated in levels. In particular, estimates of the income elasticity of UK money demand and imports are relatively more stable than those for the US, as in the case of the corresponding long-run income elasticities.

The approximately 95% confidence intervals for the estimated short-run income elasticities suggest that estimates for the US $m2$, and UK $m4$ are not statistically different from unity in most of the data vintages; see Figure 5. In contrast, income elasticity estimates for the US $m1$ and particularly those for the UK $m0$ are significantly below unity.

Results for the import demand equations suggest that estimates of the short-run income elasticity estimates for the UK are close to 0.9, but not significantly different from unity at about the 5% level of significance. In contrast, the short-run estimates for the US are close to 1.5 and significantly different from unity at the 5% level of significance. The variation in income elasticity estimates across countries and their estimated levels are consistent with much earlier evidence; see e.g. Goldstein and Khan (1985) and Marquez (2002).

4.3 Revisions in measures of macroeconomic disequilibria

Figures 7–9 present revisions in measures of disequilibria in money stock, money growth and import level and import growth. These revisions reflect revisions in their models' left-hand side and right-hand side variables as well as their parameter estimates. Our overall impression is that real time analyses, employing all available observations from the latest vintages at each point in time, are prone to large and persistent revisions. Characteristics of revisions in measures of excesses differ widely across data vintages, countries, monetary aggregates and depend on whether the variables are in levels or in difference terms. In particular, revisions in excess money and import growth rates are smaller and less persistent than those in excess money stocks and import levels.

In detail, for the US *m1* and *m2*, the top panel of Figure 7 shows revisions in excess money stocks in the ranges −14 to 10% and −9 to 6%, respectively. As expected, underestimation of GDP and overestimation of money and vice-versa, tend to amplify revisions in macroeconomic excesses; cf. Figures 1–2. For the UK *m0* and *m4*, revisions in excess money stocks are in the range -14 to 17% and -12 to 20%, respectively. In contrast, revisions in excess money growth for both the US and the UK are mostly within the range -4 to 4% and often within the even smaller ranges −2 to 2%; see Figure 8. This suggests that revisions in measures of excess money in growth form are mostly around 1/4 of revisions in excess money stocks. Figure 9 suggest comparable results for the case of US and UK imports. It shows the range of revisions in measures of excess import level to be about −17 to 20% and −16 to 13%, respectively, for the US and the UK. In contrast, revisions in excess growth rates of imports are mostly within the range -4 to 4%.

Even though revisions in measures of excess growth rates are substantially smaller than corresponding levels, they remain substantial from a policy perspective. Notably, the extent of revisions in measures of excess money growth rates as well as for revisions in their levels for the two different countries are largely comparable to target rates for broad money growth and misses from such targets for countries that recently underwent economic adjustment programs; see e.g. IMF (2004). For IMF supported programs during the period 1995–2000, target rates of broad money growth in the year following the program approval were in the range 10–16%, while projection errors or misses from targets for broad money growth were in the range −7 to 15%, except in one case where the projection error was 25%; see IMF (2004, Tables 8 and 10).

[Figure 7 about here.]

[Figure 8 about here.]

[Figure 9 about here.]

5 Contribution of data revisions

Revisions in parameter estimates could be due to changes in the sample period and length associated with changes in data vintages and/or due to data revisions. In the following, we investigate the contribution of data revisions to revisions in parameter estimates and measures of disequilibria. To this end, we fix the sample period and (hence) the number of observations and make estimates and predictions by only varying the data vintage. In this exercise, we choose data vintages from the later periods to obtain a sufficient number of observations for model estimation. Specifically, we fix the sample periods to be 1973q1–1989q4 and examine effects of estimating models on data vintages marked 1990q1–2005q4. The conclusions are qualitatively not sensitive to the choice of the sample period.

In sum, we find the contribution of data revisions to revisions in parameter estimates to be relatively small and most of the parameter estimates, especially those of slope coefficients, to be relatively stable in response to data revisions. Hence, revisions in measures of economic excesses observed in Figures 7–9 are mostly due to revisions in values of variables entering the models. The revisions in measures of economic excesses solely due to data revisions, though small, remain substantial from a policy perspective, however.

In detail, Figures 10 and 11 suggest that the contribution of data revisions to revisions in the parameter estimates is small, except in the case of the intercept term of US $m2$ and the US imports. The estimated intercept shifts from about –0.6 to –0.3 in the former case and in the range –0.1 to 0.5 in the latter case solely due to data revisions. Slope coefficients in equations of money demand and imports are relatively robust to data revisions. This also applies to estimates of slope coefficients in equations of growth in money and imports (not reported).

[Figure 10 about here.]

[Figure 11 about here.]

The evidence of relatively small effects of data revisions on parameter estimates, especially of slope coefficients, presented in Figures 10 and 11 are based on fixed sample sizes of about 20 years: 1973q1–1989q4. One could argue that the effects of measurement error as represented by data revisions on parameter estimates largely average out on samples of such sizes leaving parameter estimates relatively unaffected by data revisions associated with different data vintages. However, we reached the same conclusions by estimating the models on sample periods of 5 years using data from data vintages marked 1990q1–2005q4, as above.[12]

[12]The evidence is available on request.

5.1 Revisions in measures of disequilibria

Revisions in measures of economic excesses are mostly due to revisions in values of the variables entering the models. This is because the contributions of revisions in parameter estimates due to data revisions are relatively small in these revisions, as the parameter estimates are relatively robust to data revisions. Observed revisions in excess levels and growth rates of money and imports will therefore mainly reflect revisions in values of the variables entering the model and hence be sample dependent.

Reflecting relatively small data revisions in the vintages marked 1990q1–2005q4, Figures 12 and 13 show that the ranges of revisions in both excess money stock and money growth rates for the US solely due to data revisions are mostly in the range –1 to 1% while those for the UK are mostly within the range –2 to 2%. For import level and import growth, however, Figure 14 shows that revisions solely due to data revisions are within the range –4 to 4% for US imports and within the range –1.5 to 1.5% in the case of UK imports.

[Figure 12 about here.]

[Figure 13 about here.]

[Figure 14 about here.]

6 Conclusions

We have investigated the scope for policy mistakes when policy is based on the Polak model, the core of the IMF's financial programming models, estimated on real-time data that may be subject to revisions. To this end, we have estimated key parameters of the Polak model and derived measures of disequilibria in money stock and growth as well as import level and import growth using real-time data for the US and the UK. Data revisions are sizable even in data from the US and the UK and may be even larger for developing and emerging economies.

We have documented substantial changes in estimates of key parameters and revisions in the measures of disequilibria across different vintages of real-time data. Revisions in measures of disequilibria reflect data revisions as well as changes in parameter estimates. Changes in estimates of key parameters are mostly associated with changes in the estimation period owing to changes in data vintages. These changes may be reflecting structural changes in the economy not taken into account by the model and/or misspecification of the model due to e.g. omission of relevant variables and functional-form misspecification. Changes in coefficients estimates solely due to revisions in data have been found to be relatively small. Therefore revisions in measures of disequilibria solely due to data revisions are relatively small given the relative stability of parameter estimates in the face of data revisions, ceteris paribus.

In particular, we find that estimates of intercept terms display more variation across data vintages due to changes in the estimation period and data revisions. Estimates of slope coefficients have been found to be relatively more stable than estimates of intercept terms, especially when we control for possible effects of the estimation period. Intercepts terms play a key role in the predictive ability of models and hence in assessments of possible disequilibria; see e.g. Hendry (1997). Accordingly, we observe relatively large and quite persistent revisions of macroeconomic excesses when the model in level form is examined on different data vintages. When models in difference forms are used, revisions of macroeconomic excesses become much smaller and less persistent across data vintages. This is mainly due to elimination of intercepts terms from the models in difference form and the observation that variables in difference form entering the model are less susceptible to data revisions than when they are in levels.

Given the relatively large contribution of parameter instability to potential policy mistakes one may conclude that a model builder should seek to eliminate avoidable sources of instability in parameter estimates such as neglect of known structural changes in the economy and model misspecification owing to omission of relevant variables and inadequacy of functional form. Relevant economic theory and econometric techniques may help reduce if not eliminate potential model misspecification. Models with variables in difference form with or without intercept terms may be considered as an alternative to models with variables in levels or to cross check results based on such models.

Yet, even though models with variables in difference form have been shown to be more robust to data revisions than models with variables in levels, substantial uncertainty in parameter estimates and measures of disequilibria may remain. One may therefore consider applying decision frameworks that explicitly acknowledges model and or data uncertainty and formulate policies that could be robust to such uncertainty. This paper also underscores the need for employing a broad set of supplementary information in addition to macroeconomic data and the continuous use of judgement to formulate a policy response that is robust to data and model uncertainty.

References

Banerjee, A., J. Dolado, J. W. Galbraith, and D. F. Hendry (1993). *Co-integration, Error Correction, and the Econometric Analysis of Non-stationary Data: Advanced Texts in Econometrics.* Oxford: Oxford University Press.

Boughton, J. M. (2004). The IMF and the force of history: Ten events and ten ideas that have shaped the institution. Working Paper 75, IMF.

Burth, R. C. and B. Chadha (1989). A simulation model for financial programming. Working Paper 89/24, IMF.

Castle, J. and C. Ellis (2002). Building a real time data base for GDP (E). In Bank of England (Ed.), *Quarterly Bulletin*, pp. 42–49. London: Bank of England.

Clark, T. E. and M. W. McCracken (2009). Tests of equal predictive ability with real-time data. *Journal of Business and Economic Statistics 27*, 441–454.

Croushore, D. and T. Stark (2001). A real-time data set for macroeconomists. *Journal of Econometrics 105*, 111–130.

Easterly, W. (2006). An identity crisis? examining IMF financial programming. *World Development 34*, 964–980.

Engle, R. F. and C. W. J. Granger (1987). Co-integration and error-correction: Representation, estimation and testing. *Econometrica 55*, 251–276.

Evans, C. L. (1998). Real-time Taylor rules and the federal funds futures market. *Federal Reserve Bank of Chicago Economic Perspectives Third Quarter*, 44–55.

Fischer, S. (1997). The real-time predictive content of money for output. *Journal of Monetary Economics 48*, 3–24.

Garratt, A., G. Koop, and S. P. Vahey (2008). Forecasting substantial data revisions in the presence of model uncertainty. *Economic Journal 118*, 1128–1144.

Garratt, A. and S. P. Vahey (2006). UK real-time macro data characteristics. *Economic Journal 116*, F119–F135.

Ghysels, E., N. R. Swanson, and M. Callan (2002). Monetary policy rules with model and data uncertainty. *Southern Economic Journal 69*, 239–265.

Goldstein, M. and M. Khan (1985). Income and price effect in foreign trade. In R. W. Jones and P. Kenen (Eds.), *Handbook of International Economics*, pp. 1042–1099. Amsterdam: North Holland.

Hansen, L. P. and T. J. Sargent (2007). *Robustness.* Princeton: Princeton University Press.

Hendry, D. F. (1997). The econometrics of macroeconomic forecasting. *The Economic Journal 107*, 1330–1357.

Howrey, E. (1996). Forecasting GNP with noisy data: a case study. *Journal of Economic and Social Measurement 22*, 181–200.

IMF (2004). Macroeconomic and structural policies in Fund-supported programs: Review of experience. Technical Report http://www.imf.org/external/np/pdr/2004/eng/macro.pdf, International Monetary Fund.

Khan, M. S., P. Montiel, and N. U. Haque (1990). Adjustment with growth: Relating the analytical approaches of the IMF and the World Bank. *Journal of Development Economics 32*, 155–179.

MacDonald, R. and J. L. Stein (1999). *Equilibrium Exchange Rates.* The Netherlands: Kluwer Academic Publishers.

Mankiw, N. G., D. Runkle, and M. D. Shapiro (1984). Are preliminary announcements of money stock rational forecasts? *Journal of Monetary Economics 14*, 15–27.

Maravall, A. and D. A. Pierce (1986). The transmission of data noise into policy noise in U.S. monetary control. *Econometrica 54*, 961–979.

Marquez, J. (2002). *Estimating Trade Elasticities.* Heidelberg, Germany: Springer.

Mikkelsen, J. G. (1998). A model for financial programming. Working Paper 98/80, IMF.

Mussa, M. and M. Savastano (1999). The IMF approach to economic stabilization. Working Paper 99/104, IMF.

Orphanides, A. (2001). Monetary policy rules based on real-time data. *Americal Economic Review 91*, 964–985.

Orphanides, A. and S. van Norden (2002). The unreliability of output gap estimates in real time. *Review of Economics and Statistics 84*, 569–583.

Polak, J. (1957). Monetary analysis of income formation and payments problems. *Staff Papers - International Monetary Fund 6*, 1–50.

Polak, J. (1998). The IMF monetary model at 40. *Economic Modelling 15*, 395–410.

Polak, J. and V. Argy (1971). Credit policy and the balance of payments. *IMF Staff Papers 16*, 1–24.

Polak, J. J. (1991). The changing nature of IMF conditionality. Essays in International Finance 184, Princeton University.

Qin, D., P. Quising, X. He, and S. Liu (2005). Modeling monetary transimission and policy in China. *Journal of Policy Modeling 27*, 157–175.

Rao, M. J. M. and R. Nallari (2001). *Macroecnomic Stabilizationa and Adjustment*. Oxford: Oxford University Press.

Reinhart, C. (1990). A model of adjustment and growth: An empirical analysis. *Staff Papers, International Monetary Fund 37*, 168–182.

Rowe, J. L. (2008). A legacy of model development. *Finance and Development June*, 4–7.

Schadler, S. (1996). How successful are IMF-supported adjustment programs? *Finance and Development 33*, 14–17.

Appendix A: Real time data for the US and the UK

The US GDP data undergoes a continual process of revisions owing to regular and benchmark revisions. It usually undergoes regular revisions for up to three years after the first releases of the data as more information comes along and the source data become more complete. In addition to regular schedules of revisions, there is a benchmark revision about every five years for the national income and product accounts, when earlier observations may be revised. Benchmark revisions incorporate new source data, possible changes in definitions of variables and changes in methodology aimed at improving the quality of data. Benchmark revisions may affect data releases over several years. For example, the October 1999 revisions raised the average growth rate of real output over the previous two decades; see e.g. for more details Croushore and Stark (2001).

As for GDP, there are two reasons for revisions in monetary aggregates. First, one receives additional data on the money stock and corrects computational and reporting errors. The data from these reports are processed irregularly with a lag of up to a year. And second, occasionally the definition of a money aggregate also changes. For example, the definition of $M1$ changed in important ways after 1978. Revisions in money stock data have been analyzed by e.g. Mankiw et al. (1984), Maravall and Pierce (1986) and Fischer (1997).

Like the US data, the UK data undergo revisions many years after their first releases. The UK data are, however, less subject to comprehensive benchmark revisions after about every five years. Nevertheless, comprehensive revisions including changes in methodology were undertaken in the late 1980s and early 1990s. The money series have also been affected by periodic re-classifications, many owing to financial innovations. Data revisions in the UK time series have been discussed in e.g. Garratt and Vahey (2006) and Garratt et al. (2008).

Appendix B: Money and import demand equations - valid long-run relationships?

We estimate static equations like (2)–(3) using the available money and import aggregates for the US and the UK and test whether the corresponding residuals may be considered stationary variables; see Engle and Granger (1987). In the latter test, we employ augmented Dickey-Fuller (ADF) models formulated as:

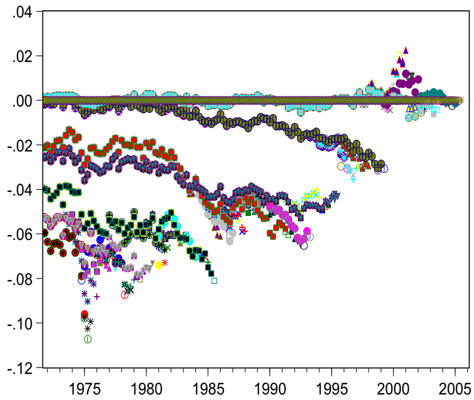
$$\Delta u_{j,t} = \varrho u_{j,t-1} + \sum_{l=1}^{k} \psi_{j,t-l} \Delta u_{j,t-l} + \xi_{j,t}, \tag{11}$$

where $u_{j,t}$ denotes the residual from the static equation for a money or import aggregate j. $\xi_{i,t}$ refers to the error term in the equation which is assumed to be a white noise, once enough lags (k) of Δu_j have been included to account for possible persistence in it. We use Dickey-Fuller distribution to test the null hypothesis of no cointegration: $\varrho = 0$. When estimating (11) for different residuals, we set the maximum number of lags, k, to 4 in all of the models.

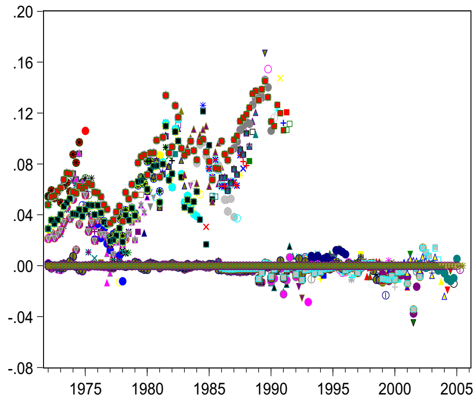
Figures 15–16 present estimates of the adjustment coefficients, denoted by $\widehat{\varrho}$s, and the corresponding t-values from the second step of the Engle-Granger procedure. These are denoted as t-ADF values.

[Figure 15 about here.]

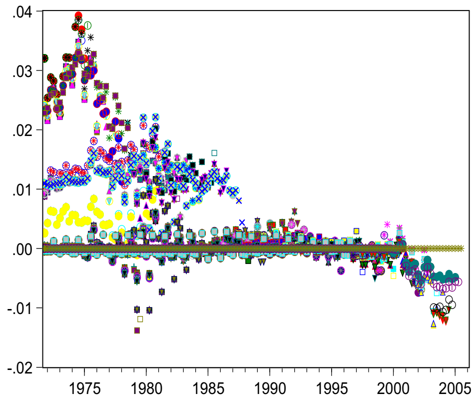
[Figure 16 about here.]



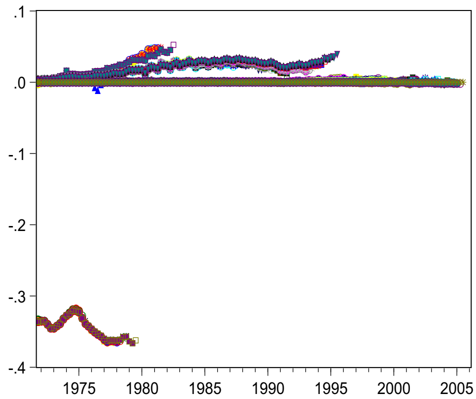
(a) US: GDP



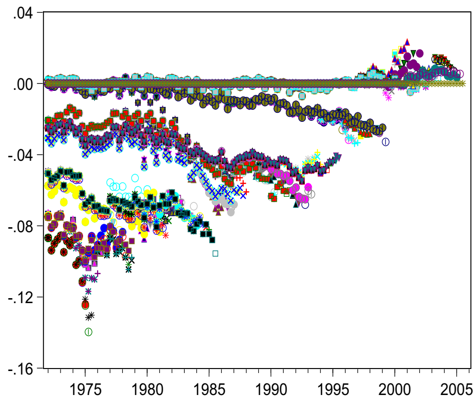
(b) US: Imports



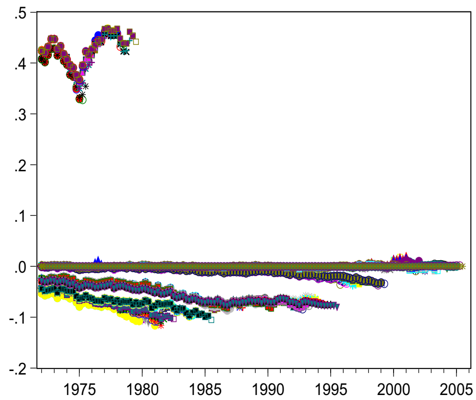
(c) US: M1



(d) US: M2

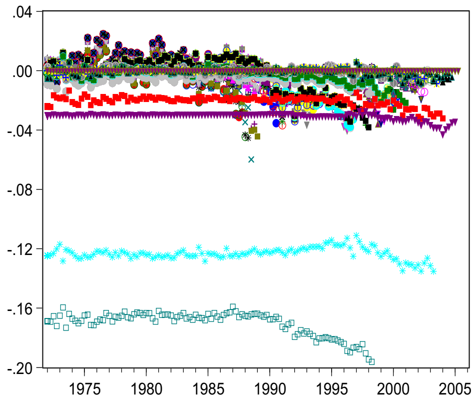


(e) US: V1

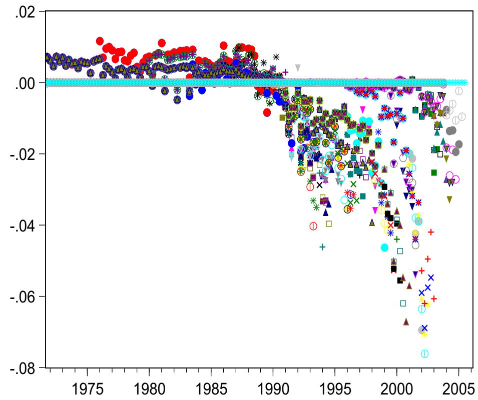


(f) US: V2

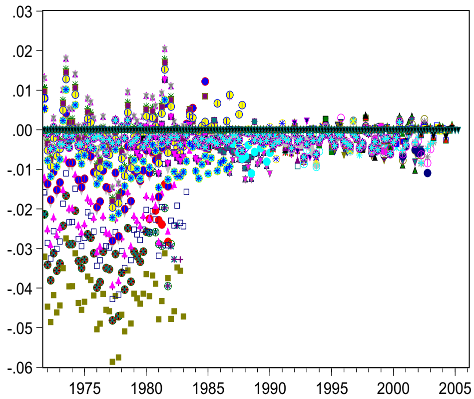
Figure 1: Revisions in the US data. Observations from vintages marked 1973q1–2005q4 are measured relative to the final vintage, 2005q4; cf. equation (6). A vintage marked period v contains observations for the period 1972q4 to $v-1$. Observations from different vintages are distinguished by different symbols and shades. The horizontal axes present periods of observations.



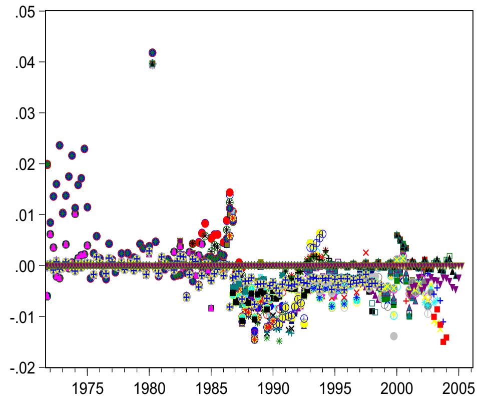
(a) UK: GDP



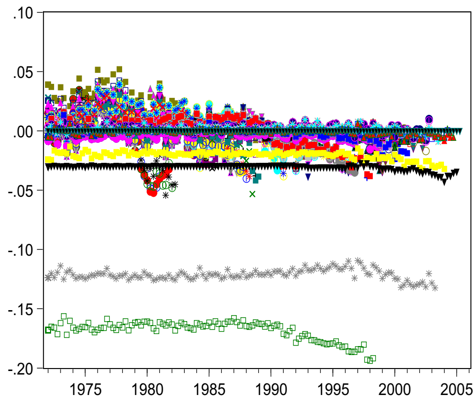
(b) UK: Imports



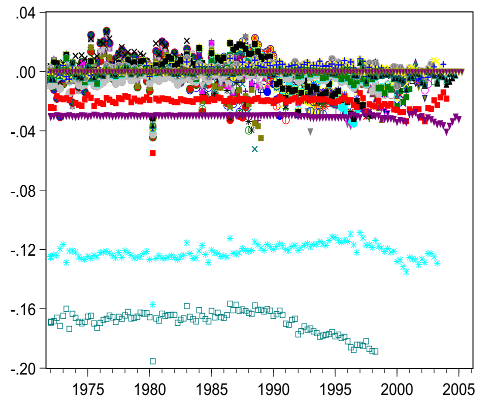
(c) UK: M0



(d) UK: M4

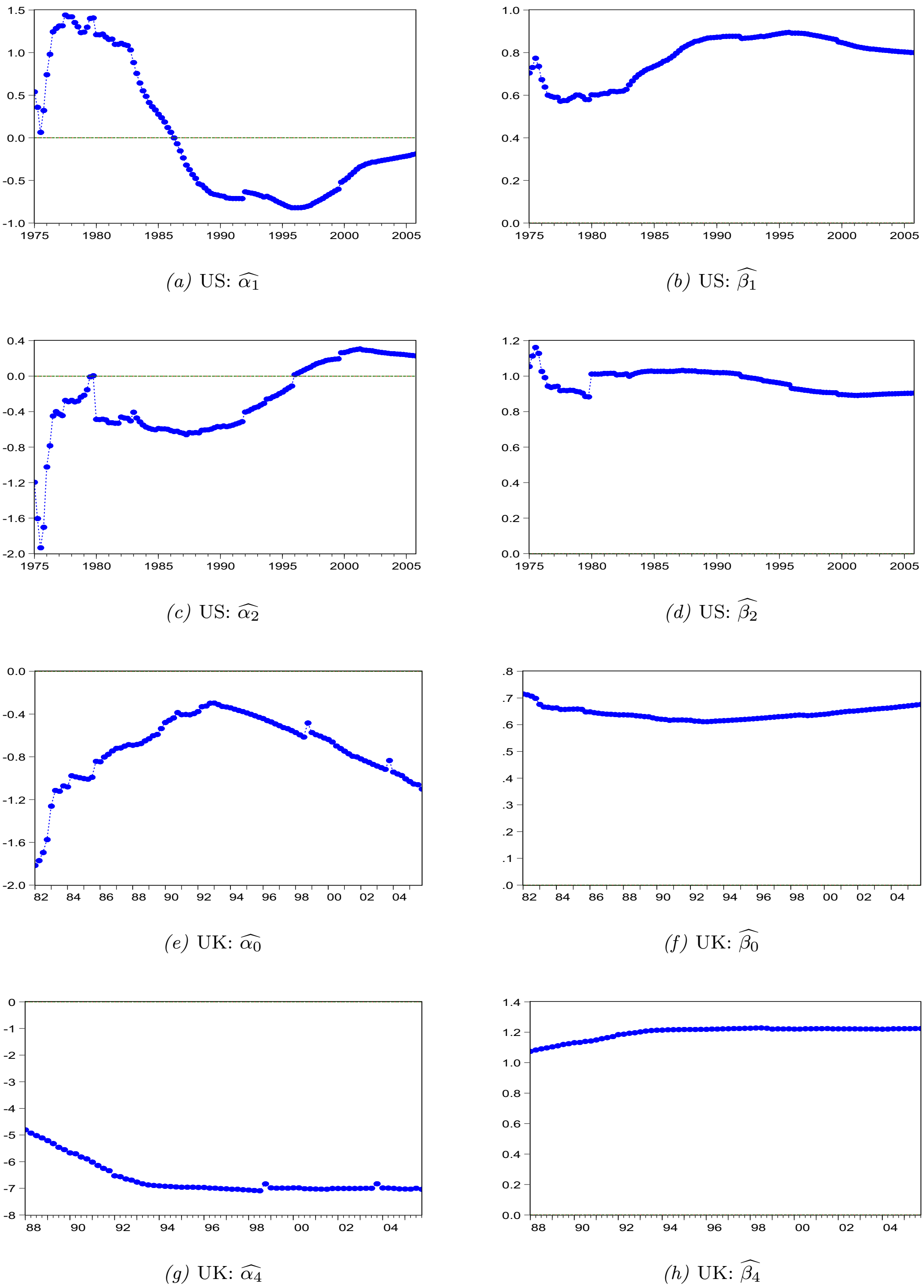


(e) UK: V0



(f) UK: V4

Figure 2: Revisions in the UK data. Observations from vintages marked 1982q1–2005q4 are measured relative to the final vintage, 2005q4; cf. equation (6). A vintage marked period v contains observations for the period 1972q4 to $v-2$. Observations from different vintages are distinguished by different symbols and shades. The horizontal axes present periods of observations.



(a) US: $\widehat{\alpha_1}$

(b) US: $\widehat{\beta_1}$

(c) US: $\widehat{\alpha_2}$

(d) US: $\widehat{\beta_2}$

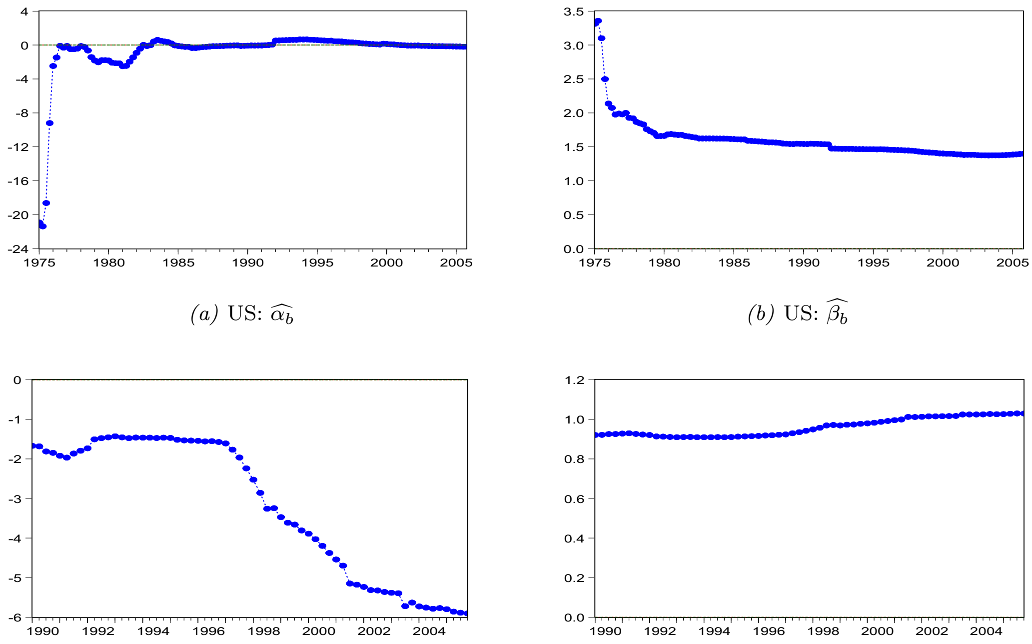
(e) UK: $\widehat{\alpha_0}$

(f) UK: $\widehat{\beta_0}$

(g) UK: $\widehat{\alpha_4}$

(h) UK: $\widehat{\beta_4}$

Figure 3: Estimates of intercept terms and income elasticities of the US $m1$ and $m2$ aggregates based on data from different data vintages; see equation (2). Each dot represents an estimate based on a sample from a different data vintage, marked on the horizontal axes. In the left-hand column, the estimates are based on observations and sample periods that increase with the maturity of the vintages. In the right-hand column, estimates are based on the same sample period for the vintages employed.



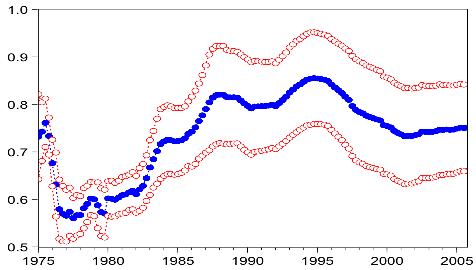
(a) US: $\widehat{\alpha_b}$

(b) US: $\widehat{\beta_b}$

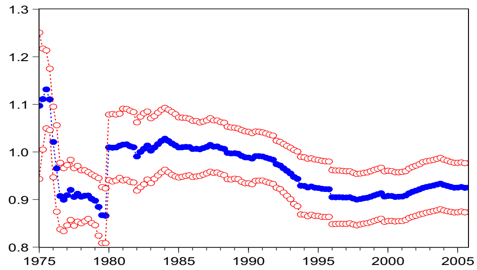
(c) UK: $\widehat{\alpha_b}$

(d) UK: $\widehat{\beta_b}$

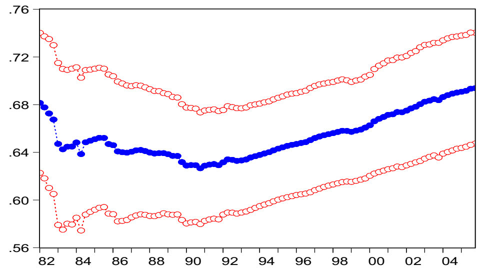
Figure 4: Estimates of intercept terms and income elasticities of imports of the US and the UK based on data from different data vintages; cf. equation (3). Each dot represents an estimate based on a sample from a different data vintage, marked on the horizontal axes. In the left-hand column, the estimates are based on observations and sample periods that increase with the maturity of the vintages. In the right-hand column, estimates are based on the same sample period for the vintages employed.



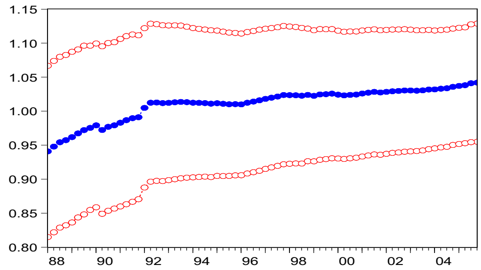
(a) US: $\widetilde{\beta_1}$



(b) US: $\widetilde{\beta_2}$

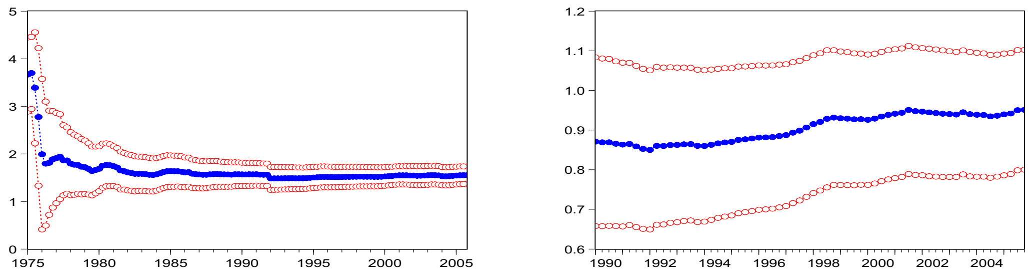


(c) UK: $\widetilde{\beta_0}$



(d) UK: $\widetilde{\beta_4}$

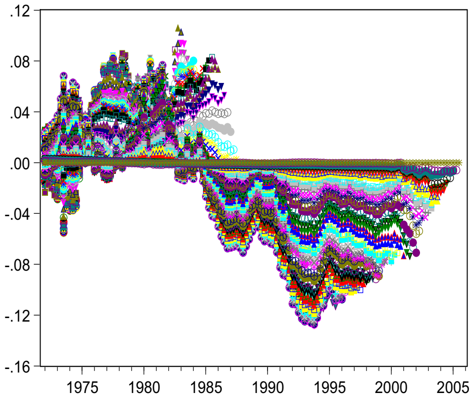
Figure 5: Estimates of short-term income elasticities, together with $\pm$ 2 times their standard errors, of monetary aggregates of the US and the UK based on data from different data vintages; cf. equation (4). Each dot represents an estimate based on a sample from a different data vintage, marked on the horizontal axes. In the left-hand column, the estimates are based on observations and sample periods that increase with the maturity of the vintages. In the right-hand column, estimates are based on the same sample period for the vintages employed.



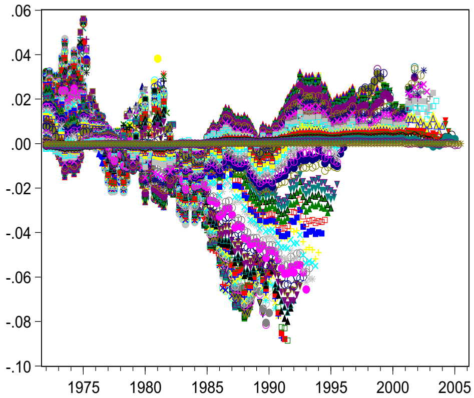
(a) US: $\widetilde{\beta_b}$

(b) UK: $\widetilde{\beta_b}$

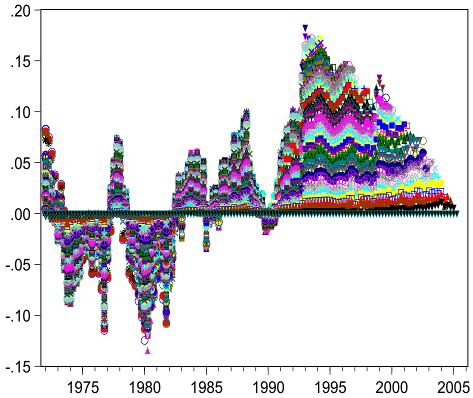
Figure 6: Estimates of short-term income elasticities, together with ± 2 times their standard errors, of imports of the US and the UK based on data from different data vintages; cf. equation (5). Each dot represents an estimate based on a sample from a different data vintage, marked on the horizontal axes. In the left-hand column, the estimates are based on observations and sample periods that increase with the maturity of the vintages. In the right-hand column, estimates are based on the same sample period for the vintages employed.



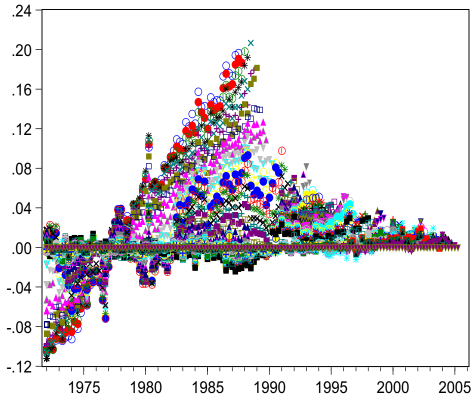
(a) US: $m1 - \widehat{m1}$



(b) US: $m2 - \widehat{m2}$

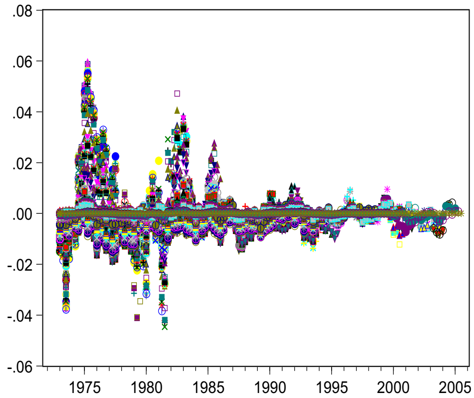


(c) UK: $m0 - \widehat{m0}$

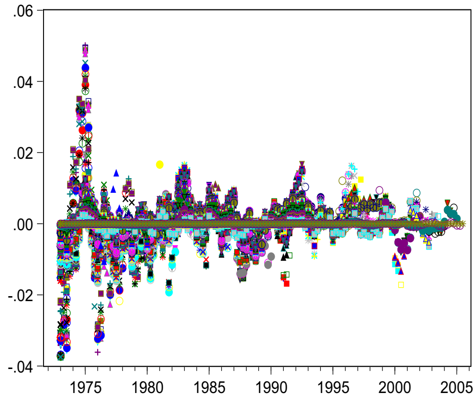


(d) UK: $m4 - \widehat{m4}$

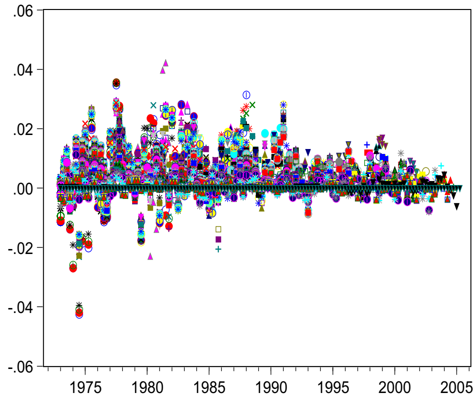
Figure 7: Revisions in the prediction errors ('disequilibria') for log values of monetary aggregates for the US and the UK based on their long-run relationships; cf. equation (7). Prediction errors for models estimated on data vintages marked 1973q1–2005q4 are measured relative to those estimated on the final vintage, 2005q4. Revisions in prediction errors corresponding to different vintages are distinguished by different symbols and shades. The horizontal axes present periods for the predicted values.



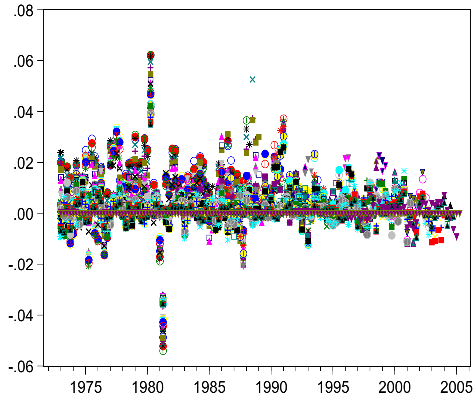
(a) US: $\Delta_4 m1 - \widehat{\Delta_4 m1}$



(b) US: $\Delta_4 m2 - \widehat{\Delta_4 m2}$

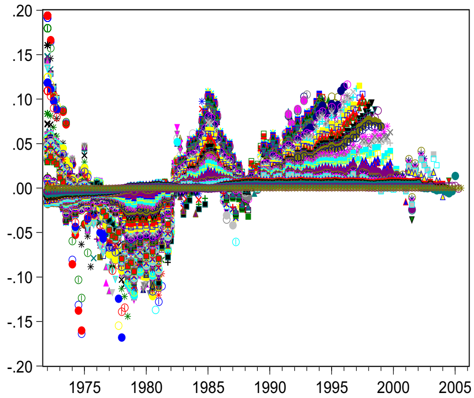


(c) UK: $\Delta_4 m0 - \widehat{\Delta_4 m0}$

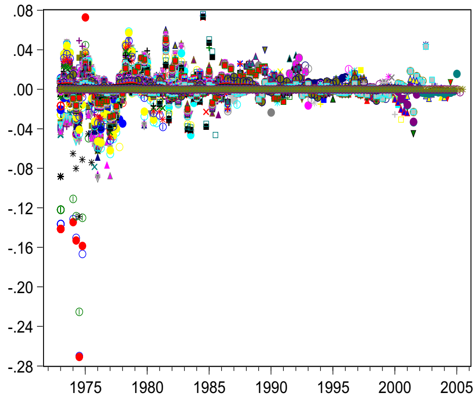


(d) UK: $\Delta_4 m4 - \widehat{\Delta_4 m4}$

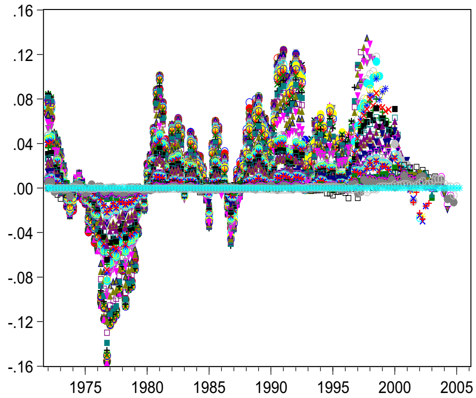
Figure 8: Revisions in the prediction errors ('disequilibria') for growth rates of monetary aggregates for the US and the UK based on their short-run relationships; cf. equation (8). Prediction errors for models estimated on data vintages marked 1973q1–2005q4 are measured relative to those estimated on the final vintage, 2005q4. Revisions in prediction errors corresponding to different vintages are distinguished by different symbols and shades. The horizontal axes present periods for the predicted values.



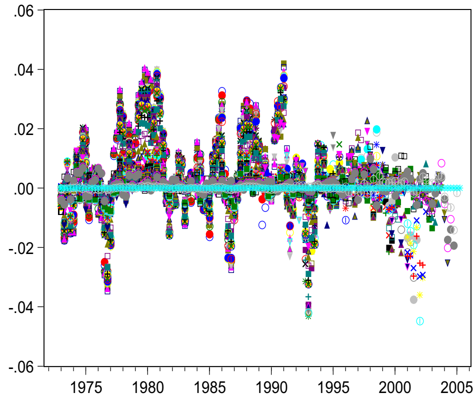
(a) US: $b - \widehat{b}$



(b) US: $\Delta_4 b - \widehat{\Delta_4 b}$

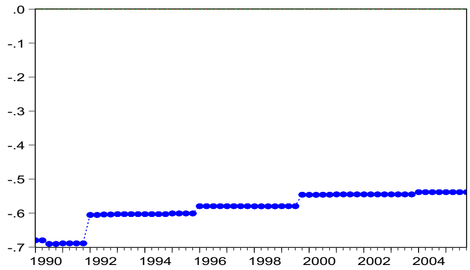


(c) UK: $b - \widehat{b}$

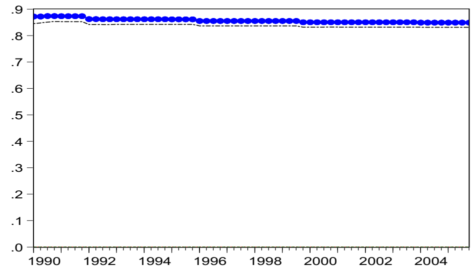


(d) UK: $\Delta_4 b - \widehat{\Delta_4 b}$

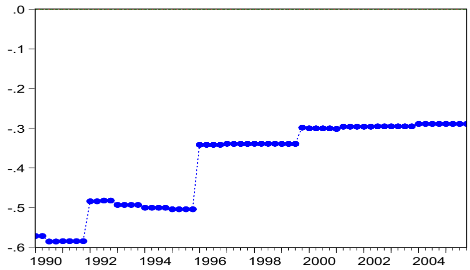
Figure 9: Revisions in the prediction errors ('disequilibria') for imports for the US and the UK based on their long-run relationships; cf. equation (9). Prediction errors for models estimated on data vintages marked 1973q1–2005q4 are measured relative to those estimated on the final vintage, 2005q4. Revisions in prediction errors corresponding to different vintages are distinguished by different symbols and shades. The horizontal axes present periods for the predicted values.



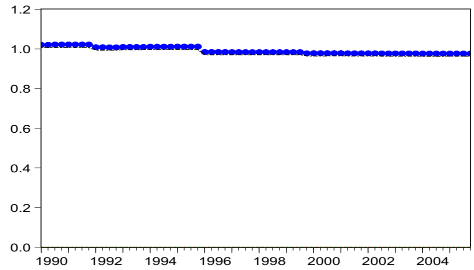
(a) US: $\widehat{\alpha_1}$



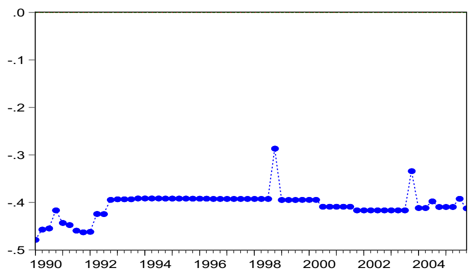
(b) US: $\widehat{\beta_1}$



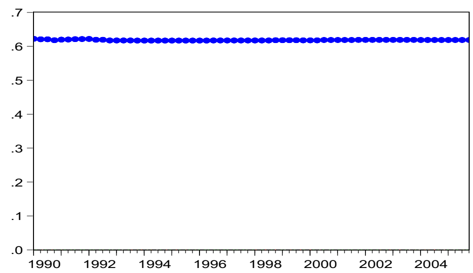
(c) US: $\widehat{\alpha_2}$



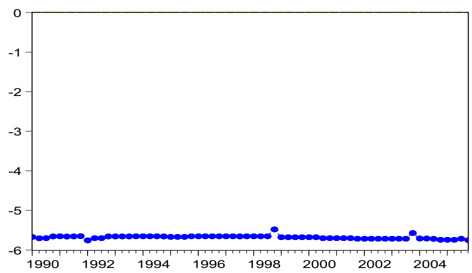
(d) US: $\widehat{\beta_2}$



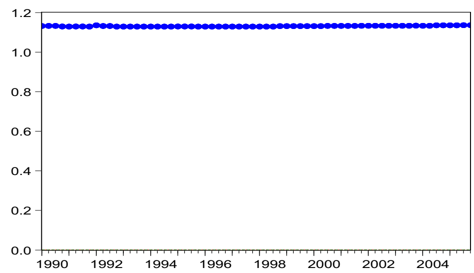
(e) UK: $\widehat{\alpha_0}$



(f) UK: $\widehat{\beta_0}$

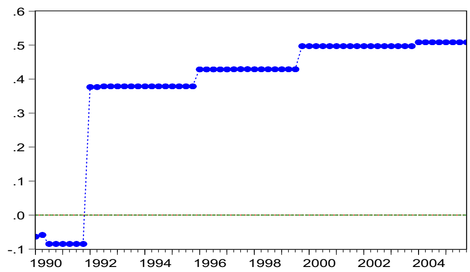


(g) UK: $\widehat{\alpha_4}$

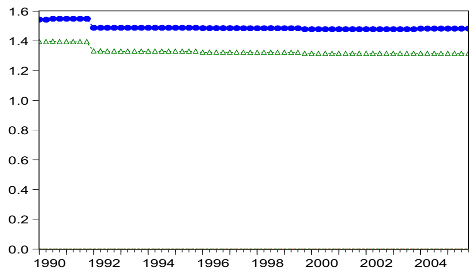


(h) UK: $\widehat{\beta_4}$

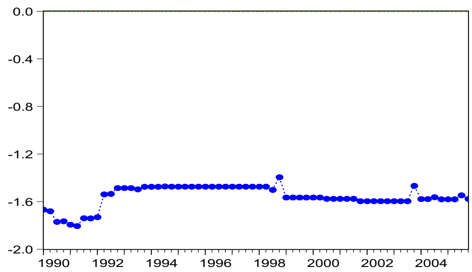
Figure 10: Estimates of intercept terms and income elasticities of the US $m1$ and $m2$ aggregates based on data from different data vintages; see equation (2). Each dot represents an estimate based on a sample from a different data vintage, marked on the horizontal axes. In the left-hand column, the estimates are based on observations and sample periods that increase with the maturity of the vintages. In the right-hand column, estimates are based on the same sample period for the vintages employed.



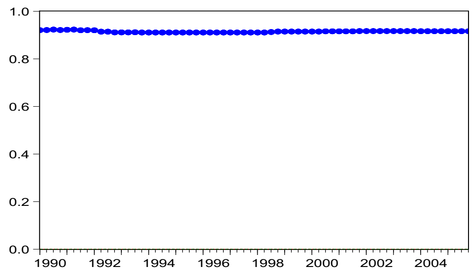
(a) US: $\widehat{\alpha_b}$



(b) US: $\widehat{\beta_b}$

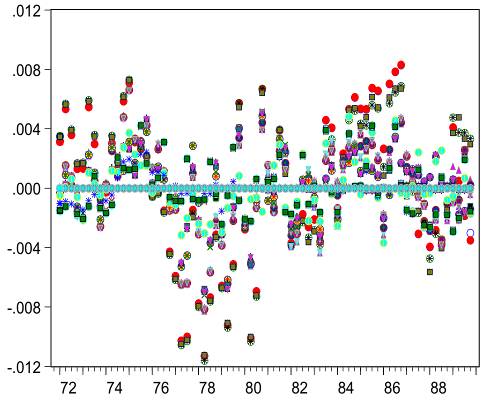


(c) UK: $\widehat{\alpha_b}$

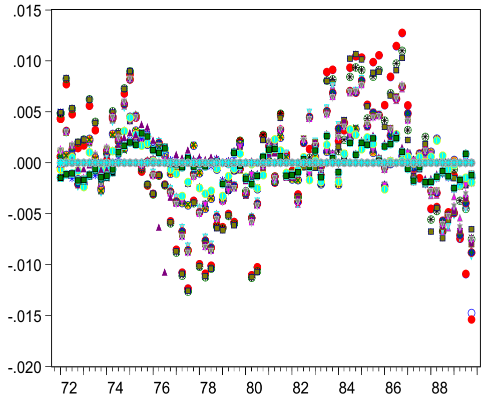


(d) UK: $\widehat{\beta_b}$

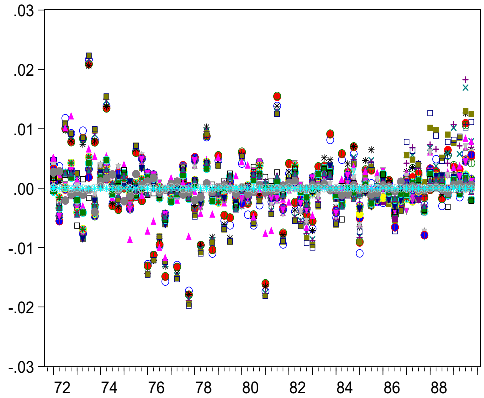
Figure 11: Estimates of intercept terms and income elasticities of imports of the US and the UK based on data from different data vintages; cf. equation (3). Each dot represents an estimate based on a sample from a different data vintage, marked on the horizontal axes. In the left-hand column, the estimates are based on observations and sample periods that increase with the maturity of the vintages. In the right-hand column, estimates are based on the same sample period for the vintages employed.



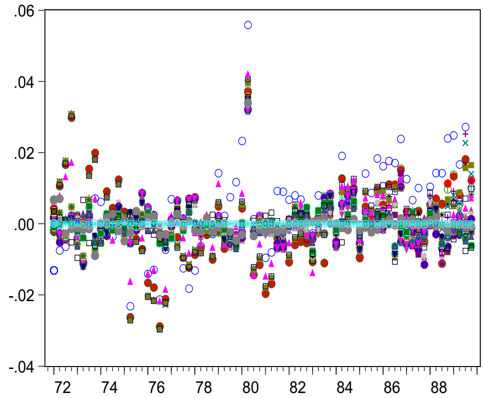
(a) US: $m1 - \widehat{m1}$



(b) US: $m2 - \widehat{m2}$

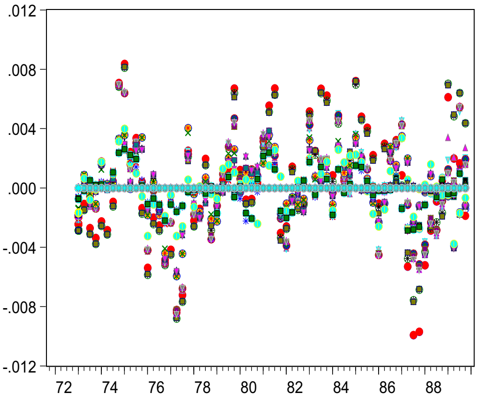


(c) UK: $m0 - \widehat{m0}$

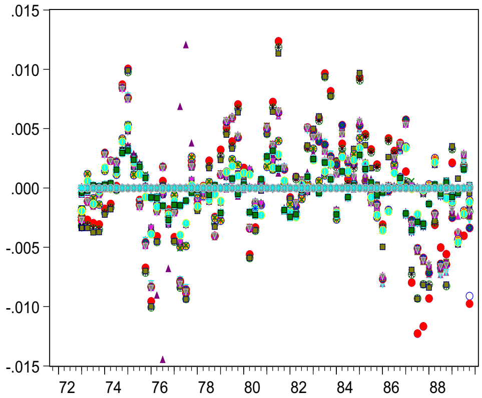


(d) UK: $m4 - \widehat{m4}$

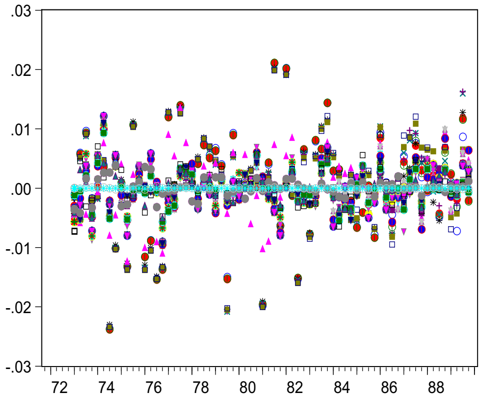
Figure 12: Revisions in the prediction errors ('disequilibria') for log values of monetary aggregates for the US and the UK based on their long-run relationships; cf. equation (7). Prediction errors for models estimated on data vintages marked 1973q1–2005q4 are measured relative to those estimated on the final vintage, 2005q4. Revisions in prediction errors corresponding to different vintages are distinguished by different symbols and shades. The horizontal axes present periods for the predicted values.



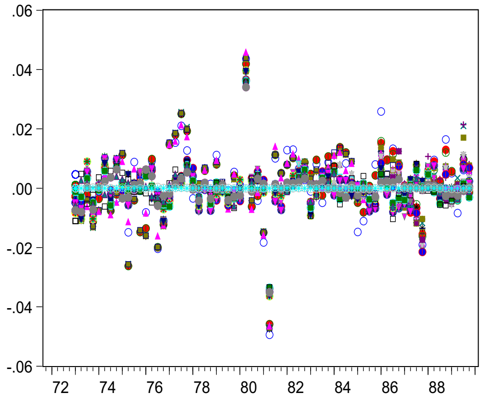
(a) US: $\Delta_4 m1 - \widehat{\Delta_4 m1}$



(b) US: $\Delta_4 m2 - \widehat{\Delta_4 m2}$

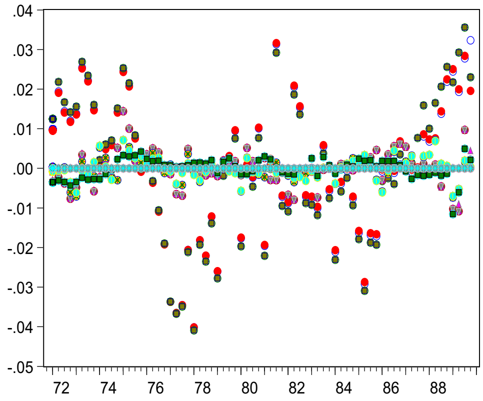


(c) UK: $\Delta_4 m0 - \widehat{\Delta_4 m0}$

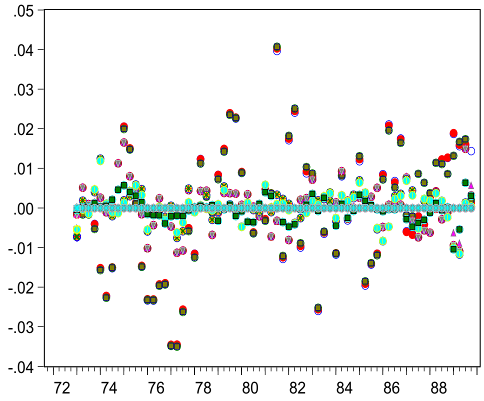


(d) UK: $\Delta_4 m4 - \widehat{\Delta_4 m4}$

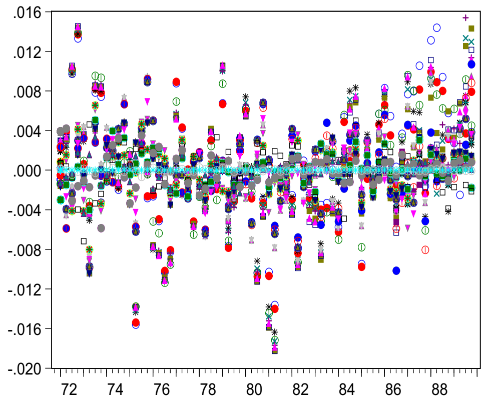
Figure 13: Revisions in the prediction errors ('disequilibria') for growth rates of monetary aggregates for the US and the UK based on their short-run relationships; cf. equation (8). Prediction errors for models estimated on data vintages marked 1973q1–2005q4 are measured relative to those estimated on the final vintage, 2005q4. Revisions in prediction errors corresponding to different vintages are distinguished by different symbols and shades. The horizontal axes present periods for the predicted values.



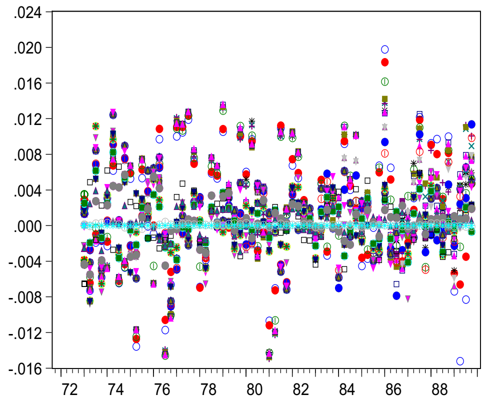
(a) US: $b - \widehat{b}$



(b) US: $\Delta_4 b - \widehat{\Delta_4 b}$

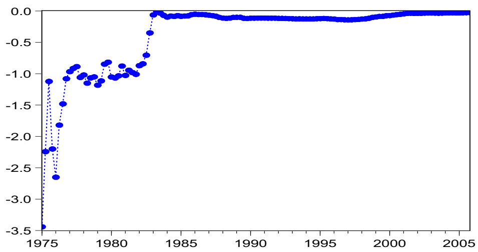


(c) UK: $b - \widehat{b}$

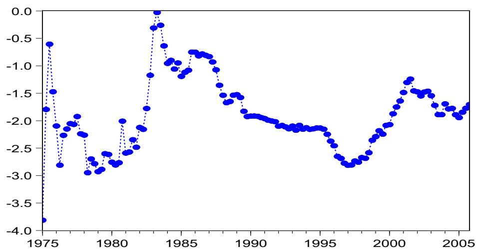


(d) UK: $\Delta_4 b - \widehat{\Delta_4 b}$

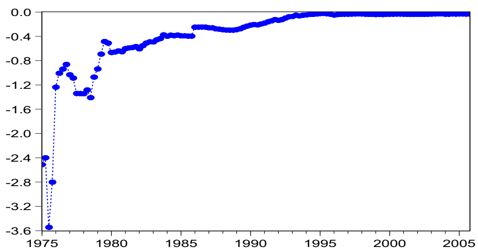
Figure 14: Left hand column: Revisions in the prediction errors ('disequilibria') for imports for the US and the UK based on their long-run relationships; cf. equation (9). Right hand column: Revisions in the prediction errors for growth rates of imports for the US and the UK based on their short-run relationships; cf. equation (10). Prediction errors for models estimated on data vintages marked 1973q1–2005q4 are measured relative to those estimated on the final vintage, 2005q4. Revisions in prediction errors corresponding to different vintages are distinguished by different symbols and shades. The horizontal axes present periods for the predicted values.



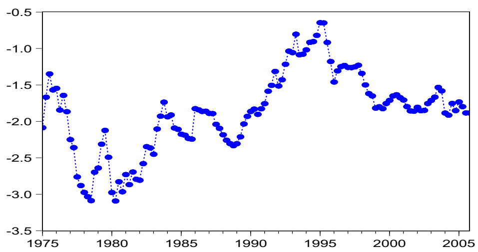
(a) US: $\widehat{\varrho_1}$



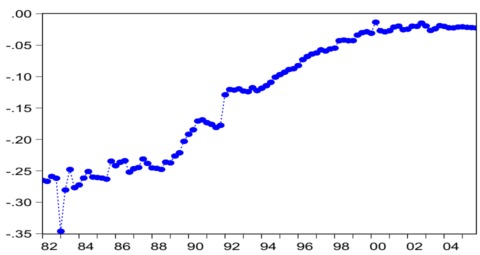
(b) US: $t_1 - ADF$



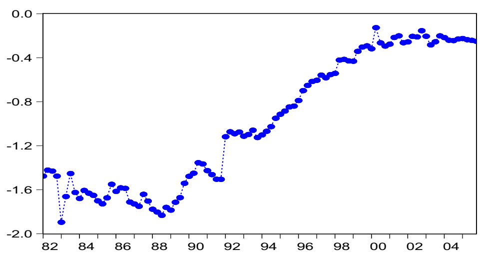
(c) US: $\widehat{\varrho_2}$



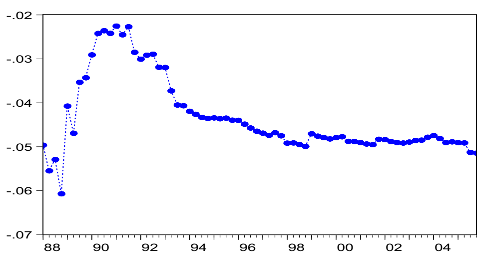
(d) US: $t_2 - ADF$



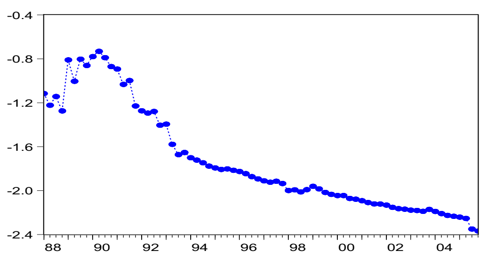
(e) UK: $\widehat{\varrho_0}$



(f) UK: $t_0 - ADF$

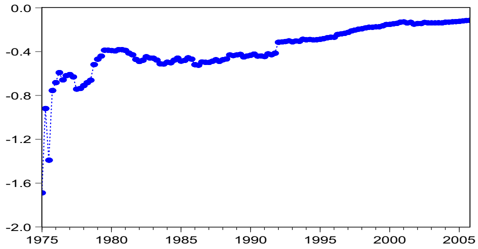


(g) UK: $\widehat{\varrho_4}$

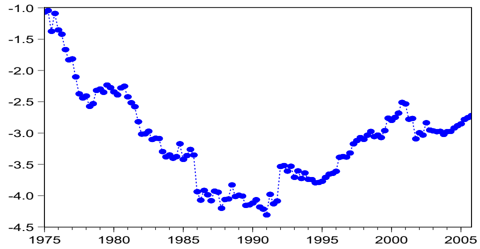


(h) UK: $t_4 - ADF$

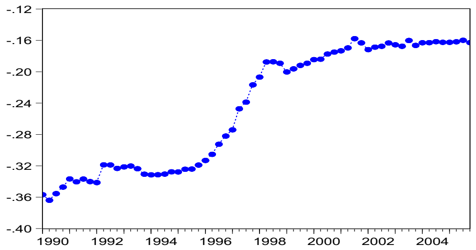
Figure 15: Cointegration tests for the US $m1$ and $m2$ relationships; cf. equation (11). Estimates of adjustment coefficient and the corresponding t-ADF values using data from different vintages. Each dot represents an estimate based on a sample from a different data vintage, marked on the horizontal axes. In the left-hand column, estimates are based on observations and sample periods that increase with the maturity of the vintages. In the right-hand column, estimates are based on the same sample period for the vintages employed.



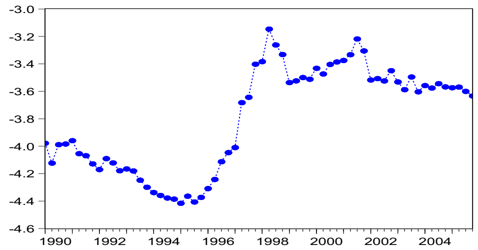
(a) US: $\widehat{\varrho}_b$



(b) US: $t - ADF$



(c) UK: $\widehat{\varrho}_b$



(d) UK: $t - ADF$

Figure 16: Cointegration tests for the import relationships for the US and the UK; cf. equation (11). Estimates of adjustment coefficient and the corresponding t-ADF values using data from different vintages. Each dot represents an estimate based on a sample from a different data vintage, marked on the horizontal axes. In the left-hand column, the estimates are based on observations and sample periods that increase with the maturity of the vintages. In the right-hand column, estimates are based on the same sample period for the vintages employed.