A Common Model Approach to Macroeconomics: Using Panel Data to Reduce Sampling Error

Authors	William T. Gavin, and Athena T. Theodorou
Working Paper Number	2003-045B
Citable Link	https://doi.org/10.20955/wp.2003.045
Suggested Citation	Gavin, W.T., Theodorou, A.T.; A Common Model Approach to Macroeconomics: Using Panel Data to Reduce Sampling Error, Federal Reserve Bank of St. Louis Working Paper 2003-045. URL https://doi.org/10.20955/wp.2003.045

Published In	Journal of Forecasting
Publisher Link	https://doi.org/10.1002/for.954

A Common Model Approach to Macroeconomics:
Using Panel Data to Reduce Sampling Error

ABSTRACT

Is there a common model inherent in macroeconomic data? Macroeconomic theory suggests that market economies of various nations should share many similar dynamic patterns; as a result, individual-country empirical models, for a wide variety of countries often include the same variables. Yet, empirical studies often find important roles for idiosyncratic shocks in the differing macroeconomic performance of countries. We use forecasting criteria to examine the macro-dynamic behavior of 15 OECD countries in terms of a small set of familiar, widely–used core economic variables, omitting country-specific shocks. We find this small set of variables and a simple VAR "common model" strongly supports the hypothesis that many industrialized nations have similar macroeconomic dynamics.

KEYWORDS: Common Model, Vector Autoregression, Panel Data, Forecast Evaluation

JEL CLASSIFICATION: C32, C33, C53, E17

Original Date: 18 December 2003, Revised 18 June 2004

William T. Gavin
Vice President and Economist
Research Department
Federal Reserve Bank of St. Louis
P.O. Box 442
St. Louis, MO 63166
Ph. (314) 444-8578
FAX (314) 444-8731
gavin@stls.frb.org

Athena T. Theodorou
Research Analyst
Research Department
Federal Reserve Bank of St. Louis
P.O. Box 442
St. Louis, MO 63166
Ph. (314) 444-8571
FAX (314) 444-8731
athena.theodorou@stls.frb.org

We thank Dick Anderson, Hailong Qian, Tom Garrett, David Kemme, and Chris Neely for helpful comments.

Introduction

There is an enormous body of cross-country research comparing specific aspects of economies. Researchers have found both similarities and differences across countries. For example, Backus and Kehoe (1992) use long time series of annual data to examine the business cycle facts across time and countries. They find that the covariance structure of real GDP and its investment and consumption components appear to be quite similar across time and countries. They find less commonality in the cyclical behavior of the government and international sectors and in the nominal variables. Florito and Kollintzas (1994) find similar results for the G-7 countries using quarterly postwar data.

Gavin and Kydland (1999, 2000) study the 1979 monetary policy change in the United States and show that although the covariance structure of real variables remains relatively stable, there are dramatic changes in the cyclical properties of nominal variables. They recommend looking for common behavior of nominal time series in countries and periods with common policy regimes. In a recent study, Kim (2002) finds similarities in the monetary policy reaction function among Germany, France, and Denmark during the 1980s and 1990s. He identifies monetary policy and exchange rate shocks and finds that they have similar effects in these economies.

In this paper, we use a multi-country data set to estimate a model with common macro-dynamic structure. We formulate and test our common-model structure in a VAR framework, subject to the restrictions of homogeneous slope coefficients and error structure. Our goal is to estimate a model that illustrates the underlying, common (or shared) macroeconomic dynamics, subject to a maintained hypothesis that the observed, historical macroeconomic dynamics of individual countries reflect a large amount of idiosyncratic variation due to one-time shocks or idiosyncratic policies. To do so, we omit from our analysis many individual country variables that, in our opinion, largely reflect historical idiosyncratic variation. For all researchers, there exists a strong temptation to include such variables in empirical studies so as to improve in-sample goodness-of-fit measures. We believe that the inclusion of such variables, even if it improves fit, often obscures the underlying common macro dynamics.

Our dataset consists of panel data for 15 OECD countries from 1980 to 2001 on output, the price level, and interest rates, all variables that have extensively been used in closed economy models.[1] We omit the money stock because preliminary work suggested that models without money generally performed better in-sample and almost always predicted better outside the estimation period. Further, individual country money supply data vanished after 1998 for the countries that have adopted the Euro. Since we are dealing with open economies, we also include a world interest rate and the exchange rate. We do not include the United States in our panel of 15 countries for two reasons. First, we assume that there exists a "world" interest rate faced by all countries and we use the U.S. interest rate to proxy for the unobservable world interest rate--hence, the U.S. long-term bond rate becomes a common variable in all the models. Second, we include in each model the exchange rate between the domestic currency vis-à-vis the US dollar.

We estimate a common specification using quarterly data for the period 1980 to 1996. We started our data set in 1980 because starting this late allows us to include a larger number of countries with consistent quarterly data from their national income accounts. We also avoid combining data from the high inflation experience in the 1970s

---

[1] Recent surveys of this literature with a concentration on the United States can be found in Christiano, Eichenbaum and Evans (1999). See Mojon and Peersman (2001) for a survey other country studies.

with data from the period of relatively stable inflation that followed. We stop in 1996 so that we can use the post-1996 data for pseudo out-of-sample forecasting comparisons.

Avoiding Overfitting

A common pitfall in macroeconomic analysis is to overfit the model to a particular sample period, leading to poor out-of-sample forecasts. Although we use VAR techniques, our common-model framework avoids the curse-of-dimensionality problem that is familiar in large, multi-country VAR studies. Economists doing empirical work in macroeconomics usually find that they have a small amount of data available relative to the complexity of the questions addressed. Whether forecasting or doing policy analysis, the short time period for which data are available means that the empirical results are weak. Part of the art of econometrics is squeezing information from data that appears to have a low signal-to-noise ratio.

The vector autoregressive (VAR) approach introduced by Sims (1980) has been criticized because the number of estimated parameters increases geometrically as the number of variables in the model increases. Several methods have been developed to deal with overfitting. Smoothing priors and Bayesian information criteria may be used to limit the number of parameters; (e.g., Doan, Litterman, and Sims, 1984). In this paper, our common-model structure addresses the same goal of reducing the number of parameters relative to the number of observations.

Stock and Watson (2003) survey the literature forecasting inflation and output using information from asset markets. They conclude that in-sample model selection criteria often fail to identify the best forecasting models. They report a great deal of instability in forecasting models. Models that work well in one episode fail in others. They also find that the median or trimmed-mean forecast from individual models often performs better than forecasts based on the standard theory of forecast combination. They attribute this result to idiosyncratic factors.

In-sample, we often reject the hypothesis that coefficient vectors estimated separately for each country are the same. Nevertheless, the rejections may be of little importance if due to idiosyncratic events. The reason is simply that macroeconomic time series are typically too short for standard methods to eliminate the effects of idiosyncratic factors. In the usual case, panel data is used to exploit the heterogeneous information in cross-country data.[2] In this case we use it to increase sample size so that we can eliminate idiosyncratic effects.

The Model

We use a small vector autoregressive model (VAR) which, for an individual country *i* may be written as:

$$Y_{it} = A_i + B_i(L)Y_{it-1} + U_{it}, \tag{1}$$

$$Y_{it} = \begin{bmatrix} y_{it} \\ p_{it} \\ r_{it} \\ e_{it} \\ R_t^{US} \end{bmatrix},\ A_i = \begin{bmatrix} a_{yi} \\ a_{pi} \\ a_{ri} \\ a_{ei} \\ a_{R^{US}i} \end{bmatrix},\ and\ U_{it} = \begin{bmatrix} u_{iyt} \\ u_{ipt} \\ u_{irt} \\ u_{iet} \\ u_{iR^{US}t} \end{bmatrix}.$$

The vector of endogenous variables, Y_{it}, includes the logarithms of five variables: real GDP (y_{it}), the GDP deflator (p_{it}), a domestic gross interest rate (r_{it}), the exchange rate vis-à-vis the U.S. dollar (e_{it}), and the gross U.S. interest rate $\left(R_t^{US}\right)$, indexed for time t and for each of our countries, i = 1 to 15. The U.S. short-term interest rate is treated as the world interest rate. Although we expect the U.S. interest rate to be determined relatively independently of the individual country variables, we include it as an endogenous variable for convenience in computing forecasts of the U.S. interest rate that are used in our multi-step-ahead forecasts. We use the log of the gross interest rates (at a quarterly rate) so that the forecast errors will be in the same scale as the other variables. A_i is a (5x1) vector of intercept terms. $B_i(L)$ is a (5x5) matrix of polynomials in the lag operator L with typical elements of the form $\sum_{j=1}^{n} \varphi_{ihkj} L^j$ where n is the number of lags in the model, and h and k are indexes over the endogenous variables $\{y, p, r, e, R^{US}\}$. U_{it} is a (5x1) vector of residuals with variance-covariance matrix, Σ_i. Within a country we assume that the disturbances are contemporaneously correlated across equations, but serially uncorrelated.

We begin by estimating the VAR separately for each country in our panel. For example, the price equation for a typical country i is given as

$$p_{it} = \alpha_{pi} + \sum_{j=1}^{n} \varphi_{ipyj} y_{t-j} + \sum_{j=1}^{n} \varphi_{ippj} p_{t-j} + \sum_{j=1}^{n} \varphi_{iprj} r_{t-j} + \sum_{j=1}^{n} \varphi_{ipej} e_{t-j} + \sum_{j=1}^{n} \varphi_{ipR^{US}j} R^{US}{}_{t-j} + u_{ipt}. \quad (2)$$

There are analogous equations for output, the domestic interest rate, the exchange rate and the world interest rate. For the individual country model forecasts, we use the 5-equation VAR system to make dynamic forecasts.

[2] For two recent examples, see Canova and Ciccarelli (2002) and Canova (2002). An exception is Bordo, Landon-Lane and Redish (2003) who assume homogeneous slope coefficients in a three-country panel.

We can view these data as a set of cross-section specific regressions so that we have 15 cross-sectional equations in each variable. We allow idiosyncratic fixed effects by including a separate intercept for each equation in each country. We do not introduce cross-country dynamics because doing so would introduce a large number of parameters and our goal is to exploit the commonality in the macro data, not to model the inter-country relationships.

Each equation in system (1) has the same set of regressors so GLS of the system is equivalent to OLS applied to each equation separately. Assuming cross-country independence, we stack the five equation system (1) for each the 15 countries to create a larger system that can be estimated using ordinary least squares.

Thus, in the common model, $B_i(L)=B(L)$, and the residual covariance matrix is given by $\Sigma_i=\Sigma$ for all i. The covariance assumptions we make can best be seen by looking more closely at the residual covariance matrix that results from our procedure. For example, in the model with N countries, and T observations on the dependent variable, we save the NxT residuals for each of the five equations, stacking them. The first T rows of this matrix are the residuals for the first country produced by the common model. The next T rows are for the second country, etc.

$$E(UU')=E\begin{pmatrix} U_1U_1' & \cdots & U_1U_N' \\ U_2U_1' & U_2U_2' & \vdots \\ \vdots & \ddots & \\ U_NU_1' & \cdots & U_NU_N' \end{pmatrix}=\begin{pmatrix} \Sigma\otimes I_T & \cdots & 0 \\ 0 & \Sigma\otimes I_T & \vdots \\ \vdots & & \ddots \\ 0 & \cdots & \Sigma\otimes I_T \end{pmatrix}=I_N\otimes(\Sigma\otimes I_T)..$$

Obviously, we are ignoring all the heteroskasticity and cross-section correlation among residuals in this procedure. These independence assumptions are quite heroic and leave open the possibility that we have miscalculated the variance-covariance matrix of the coefficient estimators. These assumptions would require deeper investigation if we were using this model to do policy analysis. However, the assumptions are less critical in this case where our goal is to evaluate out-of-sample forecasts.

The Data

The countries included are Australia, Austria, Belgium, Canada, Finland, France, Germany, Italy, Japan, Korea, Netherlands, Norway, Spain, Switzerland and the United Kingdom. Detailed data definitions and sources for each country are listed in the data appendix. We have data from 1980:Q1 to 2001:Q4. Descriptive statistics for the individual countries are given in Table 1**.** The table shows the annualized growth rates of output, the price deflator, and the exchange rate vis-à-vis the U.S. dollar. We also show the average level of the annualized interest rate over the period. At the bottom of Table 1, we show the 15 countrywide averages and the standard deviation among the country averages for the whole period and for the initial periods of estimation (1980:Q1 to 1996:Q4) and forecasting (1997:Q1 to 2001:Q4).

Real output growth rates were similar in both sub-periods, although slightly higher and less disperse in the recent period. The biggest differences were in the nominal variables. There was a pronounced decline in average inflation and interest rates in the second period as well as some convergence among the 15 countries. On average, the currencies depreciated against the dollar at a faster rate in the last 5 years of the sample. Throughout the entire 22-year period, only the Japanese Yen on average appreciated against the dollar.

The Results

Tests for the best lag length

We examine lag lengths from one to four in the common model. We perform tests with a common lag in all equations, as well as with different lags in each equation but with a common lag for all of the variables included in a single equation. Table 2a shows the results under the constraint that the correct lag order is the same in all equations. We find that the Akaike Information Criterion (AIC) is minimized at 2 lags and the Schwartz Bayesian Criterion (SBC) is minimized at 1 lag. Table 2b reports the results when we allow the lags to be different for each equation, but common for all the variables included within an equation. We find that the four lags minimized the AIC for the output and the exchange rate equations. The price equation was best with one lag and the interest rate with three lags. When we used the SBC, we found that this criterion was minimized with one lag for output, inflation and the interest rate, while 2 lags were best for the exchange rate.

Likelihood ratio tests showed that the estimated covariance matrices for lag orders 1 to 4 did not differ significantly. Because the tests were inconclusive, we decided to present results for each of the four lag specifications.

The estimated models

The sums of the coefficients for the lagged variables in each equation are shown in Table 3. The equations are arranged in four columns. For each lagged variable, we report, from the top down, the sums of the coefficients on the lagged variables for 1, 2, 3 and 4 lags. An asterisk indicates that we could reject, at the 5 percent level, the restriction that the lagged coefficients for this variable are jointly equal to zero in the common model--a multivariate Granger causality test.

For the common model, the sums of the lagged dependent variables are close to unity and the off diagonal sums are often relatively close to zero. The exceptions are the interest rates that tend to have significant and relatively large non-zero weight in explaining the other variables. The sum of the weights on the own interest rate are large and significant in both the output and price equations. The U.S. interest rate also shows up in the equations with the largest weight in the exchange rate equation. For most of the lag combinations, the other variables help to explain the GDP equation and GDP tends to enter significantly in the other equations.

Although we do not report the individual country results here, we found that there was a great deal of dispersion among the country models. Furthermore, the common model coefficients are not approximately equal to the averages of the individual country model parameters. With the exception of the exchange rate equation, the sum of the off-diagonal terms is usually close to zero. The one-lag model results are reminiscent of the random walk prior suggested by Doan, Litterman and Sims (1984). However, in the case of the multi-lag models, these off-diagonal sums that are close to zero often mask significant offsetting effects.

Homogeneity Tests

In this section we conduct homogeneity tests, asking whether it is likely that the common model could have generated the individual country data. First, we recover the residuals from the panel regressions using our common model assumption. We also recover the residuals from models estimated using only data from the individual countries and construct likelihood ratio tests comparing the variance/covariance matrix from the common model with the matrices of residual covariances from the individual country models. The results for models with 1 to 4 lags are reported in Table 4. The number of rejections declines with an increase in the lag length. With a 5 percent critical region, the number falls from 12 rejections in the case of 1 lag to 6 rejections in the case of 4 lags. Clearly, the common model is missing much of the in-sample variation in the data. The rationale for our method is that the pooled sample will be large enough to filter out the effects of idiosyncratic events that dominate the estimation process in short samples. We also think that the longer lags may help to capture macroeconomic dynamics. If this is correct, then the common model should work better than the individual country model when we include longer lags and forecast at longer horizons.

The Forecasts

We compare the forecast accuracy of the individual country models with the common models in a simulated out-of-sample experiment. We calculate four forecasts with increasing horizons at each point in time—one-quarter ahead to four-quarters ahead. The first forecasts are made using data through 1996:Q4. The forecasts are recursive; that is, we re-estimate the models with the addition of information for each quarter. Our data end in 2001:Q4 so we have 20 one-step-ahead forecasts, 19 two-step ahead, and so forth. There are 960 forecasts from each model—4 forecast horizons for each of 4 lag specifications in each of the 4 equations for each of the 15 countries. We also include a random walk forecast for comparison. The random walk models for output and the price level (but not for the interest rate or the exchange rate) include a drift term that is equal to the average growth rate for the sample period that is used to estimate the VARX models.

The root mean squared errors (RMSEs) for the four-step-ahead forecast that were computed using models with four lags are shown in Table 5. These results are typical for all the cases we considered.[3] For each equation and each country we shade the lowest RMSE among the three forecasts. Of the 60 comparisons, the RMSE from random walk forecast was lowest 20 times, the RMSE from the individual country model was lowest 7 times, but tied with the common model once, and the RMSE from the common model was lowest 32 times. In the 960 cases, the random walk model had the lowest RMSE 30.8 percent of the time, the individual country models had the lowest values 14.3 percent of the time and the common model RMSEs were lowest 54.8 percent of the time.

We use Wilcoxon Signed-Rank (WSR) statistic (with a 5 percent critical region) to test for significant differences in the accuracy of the forecasts between the individual country and common models. This statistic is calculated separately for each experiment where the forecast sample size is in the interval [17, 20]. Note that this is a nonparametric test and not a test for the equality of the RMSEs from the alternative models. Diebold and Mariano (1995) have shown that the WSR test is well sized and has more power than parametric alternatives in situations like ours where the sample is small and the forecast errors are highly correlated.

We find significant differences in accuracy between individual country model forecasts and the common model forecasts. The top panel of Table 6 reports the results by forecast horizon. At the one-quarter forecast horizon, the country model produces significantly more accurate forecasts 3.3 percent of the time, while the common model is significantly more accurate 26.7 percent of the time. As the forecast horizon becomes longer, the significant differences occur more frequently for both the individual country models and the common model. At four steps ahead, the individual country models are significantly more accurate 8.3 percent of the time and the common model is significantly more accurate 39.6 percent of the time. For the four equations, at every horizon, the panel forecasts are significantly more accurate more often than are individual country model forecasts. The biggest differences are for the exchange rate and the interest rate.

There are some differences across the forecast horizon, but it is difficult to see a pattern. For the individual country models, we see that the forecasts for output, the price level and the interest rate at more accurate (relative to the common model) the longer the forecast horizon. Although the common model is significantly more accurate much more often than the individual country model, the exchange rate was the only equation for which the performance clearly improves at the longer forecast horizon.

In the bottom panel of Table 6 we report the results by model lag length. On average, the individual country model performance deteriorates as more lags are added to the model. However, the deterioration is not monotonic for any of the individual equations. The common model performance is not so easy to characterize. On average, it did best with 3 lags and worst with 2 lags. However, for output the worst performance was at one lag—it did almost as poorly as the individual country model. For the price level, the best performance was with 4 lags; for the interest rate the best performance was with one lag.

The results by forecast horizon and by country are shown in Table 7. Japan is the only country in which the individual country model outperforms the common model—

[3] This is one of 16 cases; the others are available on the corresponding author's website.

although the common model was more accurate at the 2-quarter horizon. The only other case was the four-step-ahead forecast for Canada where the individual model was significantly better in 2 of 16 cases and the panel model was better in only 1 case.

Overall, the test for significant differences in forecast accuracy overwhelmingly favors the common model over the individual country models.[4]

Conclusion

Our goal in this paper is to estimate a common macroeconomic model for market-type economies. The basic premise underlying this paper is that a pooled cross-section of macro data can be used to uncover economic relationships that are only weakly present in the data for an individual country. The ability to explain the data well in any individual country often relies on capturing the effects of idiosyncratic factors. However, good in-sample fit does not necessarily mean good out-of-sample forecasts.

We pool quarterly data from 15 OECD countries and estimate a reduced-form VARX that is used to predict output, the price level, the interest rate and the dollar exchange rate. Our aim is not to exploit cross-country relationships and the heterogeneity in the data, but to reduce sampling error in the search for a common model. Individual country data often reject the homogeneity assumption of the panel model. Nevertheless, the out-of-sample forecasts from the common model are significantly more accurate than the forecasts from the individual country models. The superior out-of-sample forecasting performance of the common model supports our hypothesis that market economies tend to have common macro-dynamic patterns related to a small number of variables.

We have ignored the cross-sectional dependencies. It is possible that the individual country models would have better forecasts if we included information from their closest trading partners. Canova (2002) presents evidence that the mean squared inflation forecast errors across the G-7 were smaller about half the time when cross-country interdependencies were taken into account. He uses a Bayesian VAR approach to reduce the number of parameters in the estimation. We have constructed a parsimonious model that could provide a alternative baseline for investigating international dependencies, but leave that for future research. Other applications of this method are also left to future research. We expect that having a common model will be particularly useful in cases where the relevant historical record is short, such as the European Union after the introduction of the common currency, post-unification Germany, and countries that have adopted dramatic reforms to open markets or to eliminate a hyperinflation.

[4] Comparisons of statistical significance with the random walk forecasts are made and reported in Gavin and Kemme (2003). The common model outperforms the random walk model for prices and output, but does no better than the random walk model for interest rates and exchange rates.

References

Backus, David K. and Patrick J. Kehoe. "International Evidence on the Historical Properties of Business Cycles," *American Economic Review* 82(4) (September 1992) 864-88.

Bordo, Michael D., John Landon-Lane, and Angela Redish. "Good versus Bad Deflation: Lessons from the Gold Standard Era," Manuscript presented at the Federal Reserve Bank of Cleveland's *Conference on Low Inflation Economies,* November 20-21, 2003.

Canova, Fabio. "G-7 Inflation Forecasts," ECB Working Paper No 151, June 2002.

Canova, Fabio, and Matteo Ciccarelli. "Forecasting and Turning Point Predictions in a Bayesian Panel VAR Model," Manuscript, University of Pompeu Fabra, June 2002.

Christiano, Lawrence J.; Eichenbaum, Martin; Evans, Charles, L. "Monetary Policy Shocks: What Have We Learned and to What End?" *Handbook of Macroeconomics* 1A, (1999) 65-148, *Handbooks in Economics* 15. Amsterdam; New York and Oxford: Elsevier Science, North-Holland.

Diebold, F. X., & Mariano, R. S. Comparing predictive accuracy. *Journal of Business and Economic Statistics* 13 (1995) 253-263.

Doan, T. R., R. Litterman, and C.A. Sims. "Forecasting and Conditional Projection Using Realistic Prior Distributions," *Econometric Reviews* 13 (1984) 1-100.

Florito, Riccardo, and Tryphon Kollintzas. "Stylized Facts of Business Cycles in the G7 from a Real Business Cycles Perspective," *European Economic Review* 38(1) (1994) 235-269.

Gavin, William T., and David M. Kemme. "Measuring the Monetary Transmission Mechanism in Transition Economies," Federal Reserve Bank of St. Louis manuscript, January 2003.

Gavin, William T., and Finn E. Kydland. "Nominal Facts and the October 1979 Policy Change," Federal Reserve Bank of St. Louis *Review* (November/December 2000) 39-61.

________, and ________. "Endogenous Money Supply and the Business Cycle," *Review of Economic Dynamics* 2(2) (1999) 347-369.

Kim, Soyoung. “Exchange Rate Stabilization in the ERM: Identifying European Monetary Policy,” *Journal of International Money and Finance* 21 (2002) 413-434.

Mojon B. and Peersman G. "A VAR Description of the Effects of Monetary Policy in the Individual Countries of the Euro Area," ECB WP No.92, 2001.

Sims, Christopher A. “Macroeconomics and Reality,” *Econometrica,* 48 (1980) 1-48.

Stock, James H., and Mark W. Watson. “Forecasting Output and Inflation: The Role of Asset Prices,” *Journal of Economic Literature* 41 (September 2003) 788-829.

Table 1: Average Growth Rates of Output, Prices, and the Exchange Rate, and the Average Interest Rate

COUNTRY	Output	Prices	Interest Rate	Exchange Rate
AUSTRALIA	3.4	4.4	9.8	3.5
AUSTRIA	2.8	2.9	10.3	0.9
BELGIUM	1.9	3.0	7.8	2.1
CANADA	2.6	3.2	8.2	1.4
FINLAND	2.6	4.3	9.3	2.6
FRANCE	1.7	3.7	8.2	2.6
GERMANY	1.8	2.8	5.8	1.0
ITALY	1.8	6.8	11.6	4.4
JAPAN	2.5	1.0	4.0	-3.1
KOREA	6.7	5.9	13.7	3.7
NETHERLANDS	2.3	2.2	6.1	1.1
NORWAY	2.7	4.5	9.9	2.7
SPAIN	2.7	6.4	11.1	4.8
SWITZERLAND	1.4	2.6	3.5	0.2
UK	2.3	4.7	8.9	2.0
1980-2001				
MEAN	2.6	3.9	8.5	2.0
ST. DEV.	1.2	1.6	2.8	2.0
1980-1996				
MEAN	2.6	4.6	9.8	0.7
ST. DEV.	1.5	1.9	3.2	2.2
1997-2001				
MEAN	2.8	1.7	4.4	6.4
ST. DEV.	1.2	1.2	2.1	2.1

Table 2a: AIC and SBC for common lag length in the model

lags	AIC	SBC
4	-35447	-34717
3	-35461	-34906
2	-35469	-35090
1	-35417	-35247

Minimum values are shaded.

Table 2b: AIC and SBC for alternative lag lengths in each equation

AIC

lags	Real GDP	GDP Deflator	Interest Rate	Exchange Rate
4	-2415	-2610	-4758	583
3	-2408	-2613	-4762	604
2	-2400	-2615	-4754	615
1	-2386	-2617	-4748	699

SBC

lags	Real GDP	GDP Deflator	Interest Rate	Exchange Rate
4	-2313	-2507	-4656	686
3	-2330	-2535	-4684	682
2	-2346	-2562	-4700	669
1	-2357	-2588	-4719	728

Minimum values are shaded.

Table 3: Sum of the lagged coefficients and Granger causality tests

Variable	Output Equation	Price Deflator Equation	Interest Rate Equation	Exchange Rate Equation
Output				
1 lag	0.997*	0.028*	0.005*	-0.028
2 lags	0.996*	0.027*	0.004*	-0.032*
3 lags	0.993*	0.025*	0.003*	-0.024*
4 lags	0.991*	0.024*	0.003*	-0.029*
Price Deflator				
1 lag	-0.007*	0.972*	-0.003*	0.005
2 lags	-0.008*	0.973*	-0.003*	0.007
3 lags	-0.007	0.975*	-0.002*	-0.004
4 lags	-0.007	0.976*	-0.002	0.004
Interest Rate				
1 lag	-0.284*	0.221*	0.880*	-0.125
2 lags	-0.333*	0.253*	0.879*	-0.218
3 lags	-0.304*	0.251*	0.887*	-0.316
4 lags	-0.286*	0.210*	0.891*	-0.348
Exchange Rate				
1 lag	0.006*	0.000	0.000	0.937*
2 lags	0.008*	-0.001	0.000	0.933*
3 lags	0.007*	-0.002	0.000	0.943*
4 lags	0.006*	-0.001	0.000	0.936*
World Interest Rate				
1 lag	-0.056	0.182*	0.090*	1.247*
2 lags	-0.097	0.170*	0.075*	0.911*
3 lags	-0.171*	0.161*	0.063*	0.755*
4 lags	-0.210*	0.144	0.052*	0.743*

Note: An asterisk denotes rejection of the hypothesis that the lag variables of this (row) variable do not 'Granger-cause' the dependent variable (column) at the 5% significance level.

Table 4: Homogeneity Tests

Country	One Lag	Two Lags	Three Lags	Four Lags
	$\chi^2(20)$	$\chi^2(40)$	$\chi^2(60)$	$\chi^2(80)$
AUSTRALIA	20.4	46.4	76.3	93.1
AUSTRIA	79.1*	102.9*	100.8*	108.1*
BELGIUM	30.4	45.4	55.6	72.6
CANADA	136.2*	150.1*	156.9*	172.4*
FINLAND	40.9*	48.8	56.8	68.0
FRANCE	44.9*	59.7*	74.1	84.3
GERMANY	58.1*	78.9*	81.8*	86.0
ITALY	36.1*	59.7*	68.5	86.5
JAPAN	59.1*	94.5*	107.7*	116.5*
KOREA	67.8*	101.8*	126.2*	130.2*
NETHERLANDS	47.7*	65.4*	79.0	99.4
NORWAY	20.6	46.5	53.2	65.7
SPAIN	48.5*	75.4*	88.0*	96.5
SWITZERLAND	62.9*	98.5*	129.8*	136.9*
UK	42.5*	66.6*	86.4*	110.4*

The homogeneity test is a test of whether the common model residuals for an individual country are likely to have been generated by that individual country's model. An asterisk denotes the null hypothesis is rejected at the 5% level.

Table 5: Country versus common model forecasts using four lags in VARX
Four-quarter-ahead RMSEs from 1997:Q1 to 2001:Q4

Country	Output forecasts			Price level forecasts		
	Random Walk	Country Model	Common Model	Random Walk	Country Model	Common Model
AUSTRALIA	0.0189	0.0249	0.0200	0.0328	0.0244	0.0195
AUSTRIA	0.0157	0.0213	0.0191	0.0156	0.0162	0.0053
BELGIUM	0.0205	0.0284	0.0186	0.0288	0.0094	0.0030
CANADA	0.0205	0.0255	0.0176	0.0288	0.0171	0.0193
FINLAND	0.0309	0.0414	0.0246	0.0290	0.0174	0.0151
FRANCE	0.0163	0.0143	0.0081	0.0340	0.0074	0.0079
GERMANY	0.0124	0.0227	0.0120	0.0263	0.0288	0.0086
ITALY	0.0092	0.0113	0.0143	0.0538	0.0155	0.0092
JAPAN	0.0278	0.0290	0.0273	0.0256	0.0143	0.0246
KOREA	0.0776	0.1870	0.0774	0.0680	0.0404	0.0465
NETHERLAND	0.0166	0.0060	0.0170	0.0153	0.0112	0.0138
NORWAY	0.0203	0.0257	0.0229	0.0735	0.0845	0.0772
SPAIN	0.0154	0.0309	0.0109	0.0396	0.0169	0.0127
SWITZERLAND	0.0122	0.0137	0.0115	0.0225	0.0086	0.0085
UK	0.0073	0.0059	0.0077	0.0263	0.0185	0.0074

Country	Interest Rate forecasts			Exchange Rate forecasts		
	Random Walk	Country Model	Common Model	Random Walk	Country Model	Common Model
AUSTRALIA	0.0025	0.0050	0.0039	0.1274	0.1729	0.1390
AUSTRIA	0.0022	0.0031	0.0049	0.1037	0.1236	0.0811
BELGIUM	0.0025	0.0040	0.0028	0.1040	0.1041	0.0845
CANADA	0.0034	0.0036	0.0032	0.0439	0.0543	0.0730
FINLAND	0.0025	0.0091	0.0044	0.0998	0.2081	0.1083
FRANCE	0.0025	0.0049	0.0029	0.1005	0.1722	0.0833
GERMANY	0.0025	0.0022	0.0022	0.1037	0.1387	0.0847
ITALY	0.0042	0.0049	0.0043	0.0935	0.1692	0.0921
JAPAN	0.0005	0.0032	0.0030	0.1156	0.1627	0.1180
KOREA	0.0082	0.0121	0.0065	0.2340	0.8904	0.2931
NETHERLAND	0.0023	0.0025	0.0024	0.1050	0.1910	0.0970
NORWAY	0.0051	0.0056	0.0036	0.0833	0.1259	0.0902
SPAIN	0.0035	0.0064	0.0043	0.1048	0.1121	0.0978
SWITZERLAND	0.0027	0.0032	0.0023	0.1000	0.1852	0.0695
UK	0.0030	0.0051	0.0026	0.0516	0.0869	0.0407

The random walk models for output and the price level include drift terms equal to the average growth rates in the samples used to estimate the VAR models.

Table 6: Frequency of the Significant Differences in Forecast Accuracy by Variable
[Using the Wilcoxon Signed Rank Test]

Panel A: Frequency of Significant Differences by Forecast Horizon

Variable	Country VAR More Accurate				Panel VAR More Accurate			
	1-step ahead	2-step ahead	3-step ahead	4-step ahead	1-step ahead	2-step ahead	3-step ahead	4-step ahead
Total [240]	3.3%	3.8%	6.3%	8.3%	26.7%	28.3%	38.3%	39.6%
Output	5.0%	5.0%	6.7%	8.3%	18.3%	13.3%	18.3%	23.3%
Price Level	6.7%	5.0%	10.0%	15.0%	18.3%	23.3%	23.3%	28.3%
Interest Rate	0.0%	3.3%	6.7%	8.3%	41.7%	30.0%	43.3%	38.3%
Exchange Rate	1.7%	1.7%	1.7%	1.7%	28.3%	46.7%	68.3%	68.3%

Panel B: Frequency of Significant Differences by Lag Length

Variable	Country VAR More Accurate				Panel VAR More Accurate			
	1 lag	2 lags	3 lags	4 lags	1 lag	2 lags	3 lags	4 lags
Total [240]	8.8%	5.0%	4.2%	3.8%	35.0%	27.1%	35.8%	35.0%
Output	10.0%	6.7%	3.3%	5.0%	11.7%	16.7%	23.3%	21.7%
Price Level	11.7%	8.3%	10.0%	6.7%	23.3%	18.3%	21.7%	30.0%
Interest Rate	10.0%	1.7%	3.3%	3.3%	50.0%	28.3%	35.0%	40.0%
Exchange Rate	3.3%	3.3%	0.0%	0.0%	55.0%	45.0%	63.3%	48.3%

Our results are based on a 5% critical level and the null hypothesis is that the forecasts from the individual country VARX are equally as accurate as the forecasts from the panel VARX.

There are 60 cases for each variable. At each step, 15 countries with 4 VARX models [with lag lengths from 1 to 4 quarters] are included.

Table 7: Frequency of the Significant Differences in Forecast Accuracy by County

Country	Country VAR More Accurate				Panel VAR More Accurate			
	One step ahead	Two step ahead	Three step ahead	Four step ahead	One step ahead	Two step ahead	Three step ahead	Four step ahead
Total	3.3%	5.4%	6.3%	8.3%	26.7%	34.2%	38.3%	39.6%
AUSTRALIA	0.0%	6.3%	6.3%	6.3%	25.0%	25.0%	18.8%	12.5%
AUSTRIA	6.3%	6.3%	18.8%	25.0%	43.8%	43.8%	43.8%	50.0%
BELGIUM	0.0%	0.0%	0.0%	0.0%	25.0%	37.5%	37.5%	50.0%
CANADA	0.0%	0.0%	6.3%	12.5%	12.5%	12.5%	6.3%	6.3%
FINLAND	0.0%	0.0%	0.0%	0.0%	25.0%	37.5%	50.0%	56.3%
FRANCE	0.0%	6.3%	6.3%	6.3%	37.5%	37.5%	62.5%	68.8%
GERMANY	0.0%	0.0%	0.0%	0.0%	31.3%	50.0%	68.8%	75.0%
ITALY	12.5%	6.3%	18.8%	18.8%	25.0%	37.5%	37.5%	43.8%
JAPAN	18.8%	18.8%	25.0%	25.0%	6.3%	31.3%	18.8%	12.5%
KOREA	0.0%	6.3%	0.0%	0.0%	18.8%	12.5%	18.8%	12.5%
NETHERLANDS	6.3%	6.3%	12.5%	25.0%	25.0%	25.0%	31.3%	31.3%
NORWAY	0.0%	18.8%	0.0%	0.0%	31.3%	25.0%	25.0%	31.3%
SPAIN	0.0%	6.3%	0.0%	6.3%	31.3%	25.0%	37.5%	31.3%
SWITZERLAND	6.3%	0.0%	0.0%	0.0%	25.0%	43.8%	43.8%	37.5%
UK	0.0%	0.0%	0.0%	0.0%	37.5%	68.8%	75.0%	75.0%

See footnotes to Table 6.

APPENDIX A: Data Sources

Our data were downloaded from Haver Econometrics who supply data from both the IMF and OECD. In most cases, the IMF or the OECD seasonally adjusted the data. In cases where they did not (for instance, some output data from the Scandinavian countries) we seasonally adjusted the series. Nominal exchange rates are not seasonally adjusted.

Australia
Output: Gross Domestic Product [SA, Mil. 97-98 A$]. Source: OECD, Haver Series: C193GDPC@OECDNAQ.
Prices: GDP: Implicit Price Deflator [SA, 1997-98=100]. Source: OECD, Haver Series: C193J@OECDNAQ.
Rate: 3-month T-Bill Rate. Source: IFS, IMF, Haver Series: C193IT@IFS.
Money: Money Supply, M3 [SA, Mil. A$]. Source: OECD, Haver Series: C193FM3@OECDMEI.
Exchange Rate: A$ to US$ exchange rate. Source: OECD, Haver Series: C193FXDA@OECDMEI.

Austria
Output: Gross Domestic Product [SA, Mil. 95 Euros] Source: OECD, Haver Series: C122GDPC@OECDNAQ. Note: this Haver Series was partially spliced using growth rates from an older data set and also, it was seasonally adjusted.
Prices: Consumer Price Index [. Source: OECD, Haver Series: C122J@OECDMEI. Note: the Haver Series was seasonally adjusted.
Rate: 3-month T-Bill Rate. Source: OECD, Haver Series: C122FRIO@OECDMEI.
Money: Money Supply, M1+Quasi-Money [SA, Mil. Euros]. Source: OECD, Haver Series: C122FM3N@OECDMEI. Note: the Haver Series was seasonally adjusted.
Exchange Rate: Euro to US$ exchange rate. Source: OECD, Haver Series: C122FXDA@OECDMEI.

Belgium
Output: Gross Domestic Product [SA, Mil. 95 Euros]. Source: OECD, Haver Series: C124GDPC@OECDNAQ.
Prices: GDP: Implicit Price Deflator [SA, 1995=100]. Source: OECD, Haver Series: C124J@OECDNAQ.
Rate: 3-month T-Bill Rate. Source: OECD, Haver Series: C124FRT3@OECDMEI.
Money: Money Supply, M3 [SA, Bil. Euros]. Source: OECD, Haver Series: C124FM3@OECDMEI. Note: the Haver Series was seasonally adjusted.
Exchange Rate: Euro to US$ exchange rate. Source: OECD, Haver Series: C124FXDA@OECDMEI..

Canada
Output: Gross Domestic Product [SA, Mil. 97 C$]. Source: OECD, Haver Series: C156GDPC@OECDNAQ.
Prices: GDP: Implicit Price Deflator [SA, 1997=100]. Source: OECD, Haver Series: C156J@OECDNAQ.

Rate: 3-month T-Bill Rate. Source: OECD, Haver Series: C156FRCD@OECDMEI.
Money: Money Supply, M1 [SA, Mil. C$]. Source: OECD, Haver Series: C156FM1@OECDMEI.
Exchange Rate: C$ to US$ exchange rate. Source: OECD, Haver Series: C156FXDA@OECDMEI.

Finland
Output: Gross Domestic Product [SA, Mil. 95 Euros]. Source: OECD, Haver Series: C172GDPC@OECDNAQ.
Prices: GDP: Implicit Price Deflator [SA, 1995=100]. Source: OECD, Haver Series: C172J@OECDNAQ.
Rate: Short Term Money Market Rate. Source: IFS, IMF, Haver Series: C172IM@IFS.
Money: Money Supply, M2 [SA, Bil. Euros]. Source: OECD, Haver Series: C172IFM2@OECDMEI.
Exchange Rate: Euro to US$ exchange rate. Source: OECD, Haver Series: C172FXDA@OECDMEI.

France
Output: Gross Domestic Product [SA, Mil. 95 Euros]. Source: OECD, Haver Series: C132GDPC@OECDNAQ.
Prices: GDP: Implicit Price Deflator [SA, 1995=100]. Source: OECD, Haver Series: C132J@OECDNAQ.
Rate: Call Money Rate. Source: OECD, Haver Series: C132FRCM@OECDMEI.
Money: Money Supply, M2 [SA, Bil. FF]. Source: OECD, Haver Series: C132FRCM@OECDMEI.
Exchange Rate: Euro to US$ exchange rate. Source: OECD, Haver Series: C132FXDA@OECDMEI.

Germany
Output: Gross Domestic Product [SA, Mil. 95 Euros]. Source: OECD, Haver Series: C134GDPC@OECDNAQ. Note: the Haver Series was partially spliced using growth rates from an older data set.
Prices: GDP: Implicit Price Deflator [SA, 1995=100]. Source: OECD, Haver Series: C134J@OECDNAQ. Note: the Haver Series was partially calculated using spliced nominal and real GDP data.
Rate: Short Term Money Market Rate. Source: IFS, IMF, Haver Series: C134IM@IFS.
Money: Money Supply, M2 [SA, Bil. Euros]. Source: OECD, Haver Series: C134SM2@OECDMEI.
Exchange Rate: Euro to US$ exchange rate. Source: OECD, Haver Series: C134FXDA@OECDMEI.

Italy
Output: Gross Domestic Product [SA, Mil. 95 Euros]. Source: OECD, Haver Series: C136GDPC@OECDNAQ.

Prices: GDP: Implicit Price Deflator [SA, 1995=100]. Source: OECD, Haver Series: C136J@OECDNAQ.
Rate: Short Term Money Market Rate. Source: IFS, IMF, Haver Series: C136IM@IFS.
Money: Money Supply, M2 [SA, Bil. Euros]. Source: OECD, Haver Series: C136SLM2@OECDMEI.
Exchange Rate: Euro to US$ exchange rate. Source: OECD, Haver Series: C136FXDA@OECDMEI.

Japan
Output: Gross Domestic Product [SA, Bil. 95 Yen]. Source: OECD, Haver Series: C158GDPC@OECDNAQ. Note: the Haver Series was partially spliced using growth rates from an older data set.
Prices: GDP: Implicit Price Deflator [SA, 1995=100]. Source: OECD, Haver Series: C158J@OECDNAQ. Note: the Haver Series was partially calculated using spliced nominal and real GDP data.
Rate: Short Term Money Market Rate. Source: IFS, IMF, Haver Series: C158IM@IFS.
Money: Money Supply, M2 [SA, Bil. Yen]. Source: OECD, Haver Series: C158FM2@OECDMEI.
Exchange Rate: Yen to US$ exchange rate. Source: OECD, Haver Series: C158FXDA@OECDMEI.

Korea
Output: Gross Domestic Product [SA, Bil. 95 Won]. Source: OECD, Haver Series: C542GDPC@OECDNAQ.
Prices: GDP: Implicit Price Deflator [SA, 1995=100]. Source: OECD, Haver Series: C542J@OECDNAQ.
Rate: 3-month T-Bill Rate. Source: IFS, IMF, Haver Series: C542IB@IFS.
Money: Money Supply, M2 [SA, Bil. Won]. Source: OECD, Haver Series: C542FM2@OECDMEI.
Exchange Rate: Won to US$ exchange rate. Source: OECD, Haver Series: C542FXDA@OECDMEI.

Netherlands
Output: Gross Domestic Product [SA, Mil. 95 Euros]. Source: OECD, Haver Series: C138GDPC@OECDNAQ. Note: the Haver Series was seasonally adjusted.
Prices: GDP: Implicit Price Deflator [SA, 1995=100]. Source: OECD, Haver Series: C138J@OECDNAQ. Note: the Haver Series was seasonally adjusted.
Rate: Short Term Money Market Rate. Source: IFS, IMF, Haver Series: C138FRCM@IFS.
Money: Money Supply, M1 [SA, Bil. Euros]. Source: OECD, Haver Series: C138FN1@OECDMEI.
Exchange Rate: Euro to US$ exchange rate. Source: OECD, Haver Series: C138FXDA@OECDMEI.

Norway
Output: Gross Domestic Product [SA, Mil. 97 Kroner]. Source: OECD, Haver Series: C142GDPC@OECDNAQ.
Prices: GDP: Implicit Price Deflator [SA, 1997=100]. Source: OECD, Haver Series: C142J@OECDNAQ.
Rate: Short Term Money Market Rate. Source: IFS, IMF, Haver Series: C142IM@IFS.
Money: Money Supply, M2 [SA, Bil. Kroner]. Source: OECD, Haver Series: C142SLM2@OECDMEI.
Exchange Rate: Kroner to US$ exchange rate. Source: OECD, Haver Series: C142FXDA@OECDMEI.

Spain
Output: Gross Domestic Product [SA, Mil. 95 Euros]. Source: OECD, Haver Series: C184GDPC@OECDNAQ.
Prices: GDP: Implicit Price Deflator [SA, 1995=100]. Source: OECD, Haver Series: C184J@OECDNAQ.
Rate: Short Term Money Market Rate. Source: IFS, IMF, Haver Series: C184IM@IFS.
Money: Money Supply, M3 [SA, Bil. Euros]. Source: OECD, Haver Series: C184FM3@OECDMEI.
Exchange Rate: Euro to US$ exchange rate. Source: OECD, Haver Series: C184FXDA@OECDMEI.

Switzerland
Output: Gross Domestic Product [SA, Bil. 90 SF]. Source: OECD, Haver Series: C146GDPC@OECDNAQ.
Prices: GDP: Implicit Price Deflator [SA, 1990=100]. Source: OECD, Haver Series: C146J@OECDNAQ.
Rate: Short Term Money Market Rate. Source: IFS, IMF, Haver Series: C146IM@IFS.
Money: Money Supply, Money + Quasi-Money [SA, Bil. SF]. Source: IFS, IMF, Haver Series: C146LM1@IFS and C146SLQ@IFS.
Exchange Rate: SF to US$ exchange rate. Source: OECD, Haver Series: C146FXDA@OECDMEI.

United Kingdom
Output: Gross Domestic Product [SA, Mil. 95 Pounds]. Source: OECD, Haver Series: C112GDPC@OECDNAQ.
Prices: GDP: Implicit Price Deflator [SA, 1995=100]. Source: OECD, Haver Series: C112J@OECDNAQ.
Rate: 3-month T-Bill Rate. Source: IFS, IMF, Haver Series: C112IT@IFS.
Money: Money Supply, M2 [SA, Mil. Pounds]. Source: OECD, Haver Series: C112FM2@OECDMEI.
Exchange Rate: Pound to US$ exchange rate. Source: OECD, Haver Series: C112FXDA@OECDMEI.

United States
US Short Term Money Market Rate. Source: IFS, IMF, Haver Series: C111M@IFS.