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ESTIMATING AND PROJECTING POTENTIAL OUTPUT USING STRUCTURAL VAR METHODOLOGY:

The Case of the Mexican Economy

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Abstract

In this paper the authors show how potential output can be estimated and projected through an approach derived from the structural vector autoregression methodology . This approach is applied to the Mexican economy . To identify demand, supply and world oil shocks, the authors assume that demand shocks do not have a permanent effect on output and that the international price of oil is exogenous to the Mexican economy in the long term. They then calculate potential output by adding the world oil and supply components to the drift in output. They find that world oil shocks have been an important source of both actual and potential output fluctuations over a sample period extending from 1965 to 1994. However , they also find occurrences of important gaps between actual and potential output.

Résumé

Dans la présente étude, les auteurs montrent qu'il est possible d'estimer et de prévoir le niveau de production potentielle en utilisant une approche dérivée de la méthode structurelle d'autorégression vectorielle. Cette approche est appliquée dans la modélisation de l'économie mexicaine. Pour identifier les chocs de demande et d'offre et les chocs de prix mondiaux du pétrole, les auteurs font l'hypothèse que les chocs de demande n'ont pas d'effet permanent sur la production et que les cours mondiaux du pétrole sont exogènes à l'économie mexicaine à long terme. Ils calculent la production potentielle en ajoutant les composantes des prix pétroliers et de l'offre à la dérive de la production. Les auteurs constatent que les chocs de prix mondiaux du pétrole ont été une cause importante de variations de la production observée et potentielle au cours de la période 1965-1994, mais découvrent également d'importants écarts entre la production observée et potentielle.

1 Introduction

Most macroeconomic models used for forecasting and policy analysis require estimates of potential output. In these models, potential output represents the level to which real GDP reverts as the effect of demand disturbances dissipates.[1] The gap between actual and potential output is a key variable determining the evolution of prices and wages. While output in excess of potential leads to higher inflation, sustained disinflation requires output to fall below potential, *ceteris paribus*. It is therefore essential to use an appropriate method to measure potential output.[2]

In this paper, we show how potential output can be estimated and projected through an approach derived from the structural vector autoregression (SVAR) methodology developed by Shapiro and Watson (1988), Blanchard and Quah (1989), and King et al. (1991).[3] This methodology involves the estimation of a vector autoregression (VAR) model for the particular economy under study. We then identify different types of shocks by making long-term assumptions based on macroeconomic theory. This approach is applied here to the Mexican economy.[4] To identify aggregate demand, aggregate supply and world oil shocks, we assume that demand shocks do not have a permanent effect on output and that the international price of oil is exogenous to the Mexican economy in the long run. We then calculate potential output by adding the world oil and supply components to the deterministic trend in output.

Even though both oil shocks and aggregate supply shocks have permanent effects on the level of production, we chose to identify them separately and to interpret them differently, mainly to reflect the historical predominance of the oil production sector in Mexico. In particular, despite negative intermediate input effects felt in many sectors of the Mexican economy, a permanent increase in the international price of oil leads to a net expansion in total domestic output in Mexico. For that reason, we refer to aggregate supply shocks as reflecting productivity or labour supply shocks, and we refer to world oil shocks as reflecting a permanent change in either supply or demand conditions in the international oil market.

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[1] Demand disturbances are defined later.

[2] For a discussion of how the estimation of potential output can affect the formulation of monetary policy, see Boschen and Mills (1990).

[3] See also Blanchard and Watson (1986) or Sims (1986) for a similar approach using short-term instead of long-term restrictions.

[4] The choice of country was motivated by ongoing work to fully incorporate Mexico into the Bank of Canada's quarterly economic projection.

The SVAR approach has many advantages over other popular methods of estimating potential output, such as trend-based methods, filter-based methods (using, for example, the Hodrick-Prescott filter),[5] the Beveridge-Nelson decomposition (either univariate or multivariate),[6] or the methodology proposed by Kuttner (1994).

First, unlike these alternative methods, the components of output that the SVAR approach identifies can be given an economic interpretation. For example, we can interpret fluctuations in potential output as being caused by certain types of shocks (with a degree of uncertainty), whereas the other methods cannot.

Second, the method that we propose takes into account the short-term dynamics of shocks on the permanent component of output, which, we argue, should be part of potential output.[7]

Third, contrary to other methods, such as those based on the Hodrick-Prescott filter, the proposed method does not require the imposition of an arbitrary smoothing parameter.

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[5] See Laxton and Tetlow (1992).

[6] See Evans and Reichlin (1994).

[7] This is discussed in Section 2, The methodology.

Fourth, since our approach is based on the estimation of a statistical model (unlike filter-based methods), confidence intervals can be derived, which gives a measure of the uncertainty surrounding the estimates of the output gap and potential output.

Finally, this method should be attractive to policy makers in that it provides a structural interpretation of the latest output data, based on information that is available when economic policy decisions have to be made (contrary to two-sided filters, which use ex post data).

The rest of the paper is organized as follows. In Section 2, we present the methodology. Section 3 describes the data. Section 4 presents our results and illustrates how the model can be used to project potential output. We conclude and discuss avenues for future research in Section 5.

2 The methodology

In order to distinguish among various sources of output fluctuation, we apply a variant of the structural VAR methodology to an autoregressive system composed of three variables. It is assumed that the rate of growth of output (y), the price of oil (o), and a monetary aggregate (m) each follow a stationary stochastic process that responds to three types of non-autocorrelated orthogonal shocks: supply shocks (εs), world oil shocks (εo), and demand shocks (εd).[8]

The structural model can be given a moving-average representation as follows:

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8. Note that a four-variable VAR including prices gave similar results. We chose to present this three-variable VAR because the presence of obvious non-linearities in Mexico's price series would have unnecessarily complicated the analysis.

$$\Delta x_t = A_0 \varepsilon_t + A_1 \varepsilon_{t-1} + \ldots = \sum_{i=0}^{\infty} A_i \varepsilon_{t-i} = A(L)\,\varepsilon_t \tag{1}$$

where

$$\varepsilon_t = \begin{bmatrix} \varepsilon s \\ \varepsilon o \\ \varepsilon d \end{bmatrix} \text{ and } \Delta x_t = \begin{bmatrix} \Delta y \\ \Delta o \\ \Delta m \end{bmatrix}$$

To simplify , the variance of the structural shocks is normalized so that $E(\varepsilon_t \varepsilon_t) = I$, the identity matrix.

To identify this structural model, the autoregressive reduced-form VAR of the model is first estimated:

$$\Delta x_t = \Pi_1 \Delta x_{t-1} + \ldots + \Pi_q \Delta x_{t-q} + e_t \tag{2}$$

where e_t is a vector of estimated residuals, q is the number of lags, and $E(e_t e_t) = \Sigma$.

Given that the stochastic process is stationary , (2) may be written as an infinite moving-average process:

$$\Delta x_t = e_t + C_1 e_{t-1} + \ldots = \sum_{i=0}^{\infty} C_i e_{t-i} = C(L)\,e_t \tag{3}$$

The residuals of the model's reduced form are thus related to the structural residuals in the following way:

$$e_t = A_0 \varepsilon_t \tag{4}$$

which implies that

$$E(e_t e_t) = A_0 E(\varepsilon_t \varepsilon_t) A_0' \tag{5}$$

and thus,

$$A_0 A_0' = \Sigma \tag{6}$$

In order to identify the structural shocks (ε) from the information obtained by estimating the VAR (equation 2), that is, from the reduced-form shocks *(e)* and their variance (Σ), we need to provide sufficient identifying restrictions to evaluate the elements in A_0. In this three-variable system, A_0 has nine elements. Since the estimated variance-covariance matrix Σ is symmetric, equation (6) provides six independent identifying restrictions. Thus, three additional restrictions must be imposed. From (1), (4) and (6), we note that the matrix of long-run effects of reduced-form shocks, that is, $C(1)$, is related to the equivalent matrix of structural shocks, that is $A(L)$, through the following relation:

$$A(1) = C(1) A_0 \tag{5}$$

where the matrix $C(1)$ is calculated from the estimated VARs.[9]

If the variables considered in this paper were cointegrated, this, in itself, would imply certain long-run restrictions.[10] However, the results of cointegration tests presented in Section 3 suggest that cointegration is not present. Therefore, three identifying restrictions are imposed on $A(1)$, based on economic theory. One of these follows from the hypothesis that demand shocks have no permanent effects on output. This implies that all shocks that have a transitory effect on the level of output are interpreted as demand shocks. This rests on the assumption also used by Blanchard and Quah and others, that in the long run output depends on factors such as productivity , demographics and permanent shifts in the terms of trade. The second and third restrictions, which allow us to distinguish between world oil shocks and supply shocks, are derived from the assumption that only the former have a long-run effect on the price of oil. Put another way , Mexico is assumed to be a price-taker on the world oil market.

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[9] $C(1)$ is the polynomial value $C(L)$ for $L = 1$.

[10] On this subject, see King et al. (1991).

World oil shocks can have a permanent effect on the price of oil, since this series follows a nonstationary process. The identified oil shocks could be demand or supply shocks on the world market. Since demand for Mexican oil is assumed to be perfectly elastic, a permanent increase in the price of oil can bring a permanent increase in Mexican oil production. Given the importance of the oil sector in Mexico, world oil shocks are expected to have a permanent effect on the output level.

Therefore, we obtain the following structural output decomposition:

$$\Delta x_t = \mu + A_s(L)\,\varepsilon_{st} + A_o(L)\,\varepsilon_{ot} + A_d(L)\,\varepsilon_{dt} \qquad (6)$$

The right-hand side of equation (7), which is composed of the moving-average components of the different types of shocks plus the deterministic trend in output (μ), can be rewritten to take into account the cyclical components of the supply and world oil shocks:

$$\Delta x_t = \mu + A_s(1)\,\varepsilon_{st} + A_s^*(L)\,\varepsilon_{st} + A_o(1)\,\varepsilon_{ot} + A_o^*(L)\,\varepsilon_{ot} + A_d(L)\,\varepsilon dt \qquad (7)$$

where the $A^*(L)$ represent the transitory components of the permanent (supply) shocks. The first five terms on the right-hand side of (8) represent our measure of the first difference of potential output. W e can then project potential output by adding the effect of past oil and supply shocks to the projected deterministic trend in output. Confidence intervals around the estimated potential output series are obtained following a standard bootstrap approach.[11]

One difference between our approach and those of Kuttner (1994) and Evans and Reichlin (1994) (based on Beveridge-Nelson decompositions) is in the treatment of the transitory components of permanent shocks $A^{*}(L)$. Kuttner identifies potential output as a random walk that is orthogonal to the cyclical component of output. The decomposition he obtains may be represented in the following way:

$$\Delta x_t = \mu + \Gamma(1)\eta_{1t} + \Gamma(L)\eta_{2t} \tag{8}$$

where x_t includes output and prices, and potential output is defined as the deterministic trend plus the permanent component (first two terms on the right-hand side), which is orthogonal to the transitory component.

In the case of the Beveridge-Nelson method (univariate or multivariate), the permanent and cyclical components are perfectly correlated. Their decomposition can be expressed in the following way:

$$\Delta x_t = \mu + C(1)\varepsilon_t + C^{*}(L)\varepsilon_t \tag{9}$$

In this context, the first difference of potential output is simply the first two terms on the right-hand side of the equation (10). Potential output is perfectly correlated with the cyclical component, which is the last term of the equation.[12]

Unlike our approach, the Kuttner and Beveridge-Nelson approaches do not take into account the transitory component of potential output. Since real-world supply shocks are likely to be characterized by such a transitory component, (for example, it is likely that the effect of a productivity shock will be felt only gradually) we think that this should be seen as an advantage of our approach.[13]

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[11] For a survey of the bootstrap method see Jeong and Maddala (1993). For an application see Runkle (1987).

[12] It is interesting to note that the discussion of equations (8) to (10) can be seen as an extension in a multivariate context of the discussion contained in Watson (1986).

Note that it is very important that the estimated VAR include a sufficient number of lags. Monte Carlo simulations done by DeSerres and Guay (1995) show that using a lag structure that is too parsimonious can significantly bias the estimation of the structural components. These authors also find that information-based criteria, such as the Akaike and Schwarz criteria, tend to select an insufficient number of lags, while Wald or likelihood ratio (LR) tests, applied according to a general-to-specific strategy, perform much better. Accordingly, we selected the number of lags (12) to be included in our VAR on the basis of such an LR test (using a 5 per cent critical value).

3 The data

We use quarterly data on industrial production and the monetary base (excluding reserves at the central bank) taken from *International Financial Statistics* (International Monetary Fund). Industrial production data, rather than real GDP data, are used, as there is no appropriate quarterly GDP series available for Mexico. The price of West Texas Intermediate crude oil, deflated by the CPI for the United States, is used as an approximation of the world relative price of oil. The sampling period extends from the second quarter of 1965 to the second quarter of 1994. The real price of oil and the year-over-year growth rates of industrial production and the monetary base are shown in Charts A-1 to A-3 of Appendix 1.

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[13] A caveat to this is that the transitory component of potential output could be partly accounted for by the systematic response of fiscal and monetary policies to supply shocks. One could argue that the effect of this systematic response should not be included in the calculation of potential output.

Our approach assumes the presence of a permanent (stochastic) component in the level of output and the price of oil. Unit-root tests could not reject these assumptions (see Appendix 2 for more details on these tests). The same tests were also applied to the monetary base. Test results indicate that this variable is stationary in first-difference form.

While unit-root tests suggest that the model variables are nonstationary in levels, it is still possible that a stationary linear combination of the variables could be found. In such a case, a vector error-correction model would have to be estimated, since estimating a VAR in first differences would remove important information about the behaviour of the variables that is contained in the common trend. We used the method proposed by Johansen (1988), and applied by Johansen and Juselius (1990), to test for cointegration between the three variables (see Appendix 2 for more details). The tests could not reject the null hypothesis of no cointegration. Consequently, we assume that the series in the model are not cointegrated and that it is appropriate to estimate the VAR models as a first difference (of the logarithms).

4 Results

This section includes four subsections. In the first, we present the variance decomposition of Mexico's output. We then present impulse responses of output to demand, oil and supply shocks. In the third subsection, we present our estimates of the cumulative effect of the different types of shocks on Mexico's potential output. Finally, we show how potential output can be projected using our methodology.

4.1 Variance decomposition

The decomposition of variance presented in Table 1 allows us to measure the relative importance of supply shocks, world oil shocks and demand shocks underlying output fluctuations over different time horizons. Since we are imposing the restriction that demand shocks have no permanent effect on output, the proportion of output variance explained by supply and oil shocks gradually approaches 100 per cent in the long run. Moreover, since all three types of shocks are uncorrelated by assumption, the proportion of the output variance caused by the sum of the three shocks is always equal to 100 per cent.

Table 1 suggests that demand shocks have played an important role as a source of output fluctuation over very short horizons.[14] However, the results also illustrate how important oil shocks have been for the Mexican economy. In effect, oil shocks appear to dominate from two quarters on. Non-oil supply shocks have less importance over the period under consideration. A caveat to this analysis is the uncertainty surrounding the numbers as illustrated by the relatively wide 90 per cent confidence intervals. This is not surprising, since most econometric studies present variance decompositions with very large confidence intervals at conventional levels. The intrinsic volatility of Mexican economic series and the large number of lags that are included in the VAR may accentuate the problem in the context of our study.

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[14] Demand shocks are more important here than in Lalonde and St-Amant (1993). This can be attributed to the method used by these authors to derive the number of lags for their VAR, which led to the selection of too few lags and may have biased the estimation of the structural components.

TABLE 1: V ariance decomposition of output
(relative contribution of the different types of shocks, in per cent)

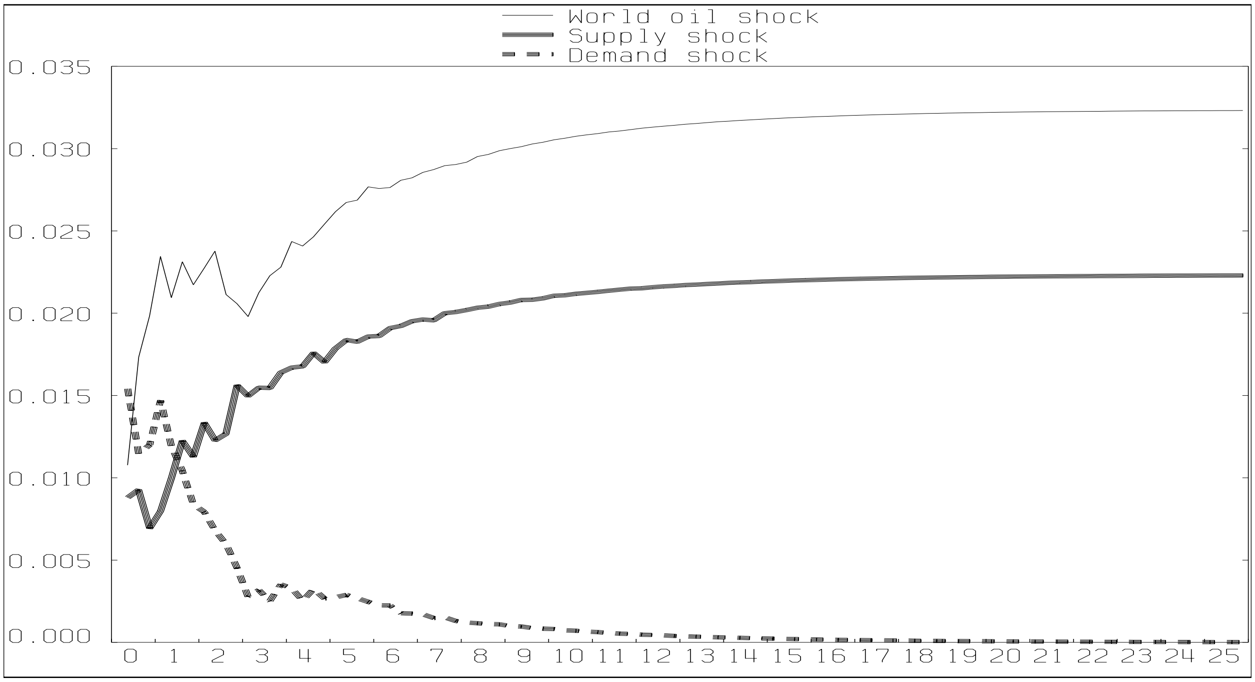
Horizon (quarters)	World oil	Supply	Demand
1	27 (2-64)[a]	18 (0-78)	55 (0-83)
2	44 (7-78)	17 (1-75)	39 (2-68)
4	58 (15-87)	12 (1-75)	31 (1-63)
8	63 (16-88)	16 (1-80)	21 (2-55)
16	65 (11-91)	24 (2-81)	11 (3-40)
32	67 (7-93)	29 (2-33)	5 (2-33)
long term	67 (5-96)	31 (1-85)	0 (0-35)

a. 90% confidence interval

4.2 Impulse responses

Chart 1 (p. 12) shows the impulse response of Mexican output to the three different kinds of structural shocks. Each shock is one standard deviation in size. The horizontal axis is the number of years. As expected, world oil and supply shocks have a permanent impact on the level of output, while most of the effects of the demand shocks disappear after four years. Note that the impact of the supply shock is felt only gradually , possibly reflecting the cost of adjustment to these shocks. The chart, again, confirms the importance of world oil shocks for the Mexican economy .

Chart 1: Response of Mexico's index of industrial production

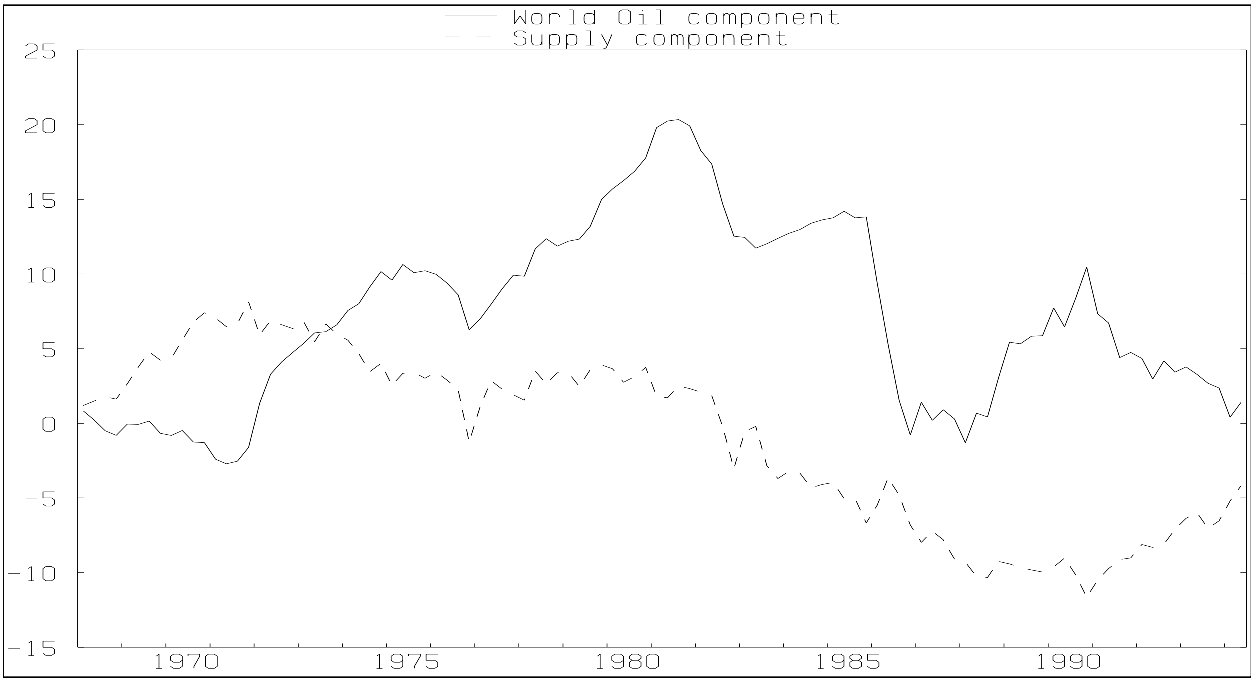


4.3 The components of output and potential output

Chart 2 shows the estimated stochastic supply components of Mexican output (the cumulated effect of oil and supply shocks), expressed in a percentage of actual output. This chart reaffirms the importance of oil for Mexico. In the 1970s, the effects of positive oil shocks, associated with the sharp increase in the price of oil (see Chart A-1 in Appendix 1), had a major impact on the level of Mexico's output. The subsequent fall in oil prices accounts for the drop in the oil component from 1982 to 1988. After some reversal in the late 1980s, the negative oil shocks again adversely affected output growth in the 1990s, reflecting the decline of the world price of oil.

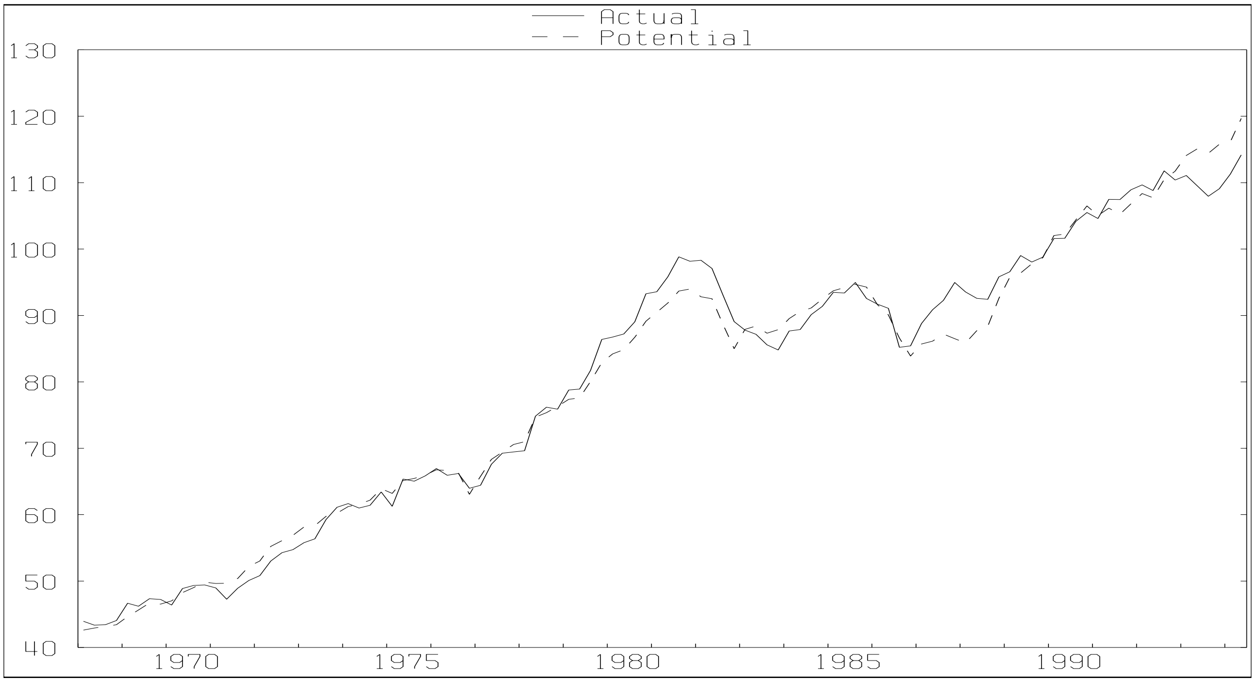
Movements in the supply component are more difficult to interpret, since they can be caused by many different kinds of shocks (demography, productivity, and so forth). However, note the recent increase in the supply component (it is less negative), which is compensating for the negative oil shock. This increase could be due to the structural reforms that have been implemented in recent years in Mexico, including the privatization that has occurred in some sectors of the economy and the opening of its external sector in the context of the North American Free Trade Agreement.

Chart 2: Supply components of output



Adding the world oil and supply components to the deterministic component (that is, the trend) of output – or, alternatively, subtracting the demand component from actual output – gives potential output, which is shown on Chart 3 (p. 14) together with actual output.

Chart 3: Potential and actual output

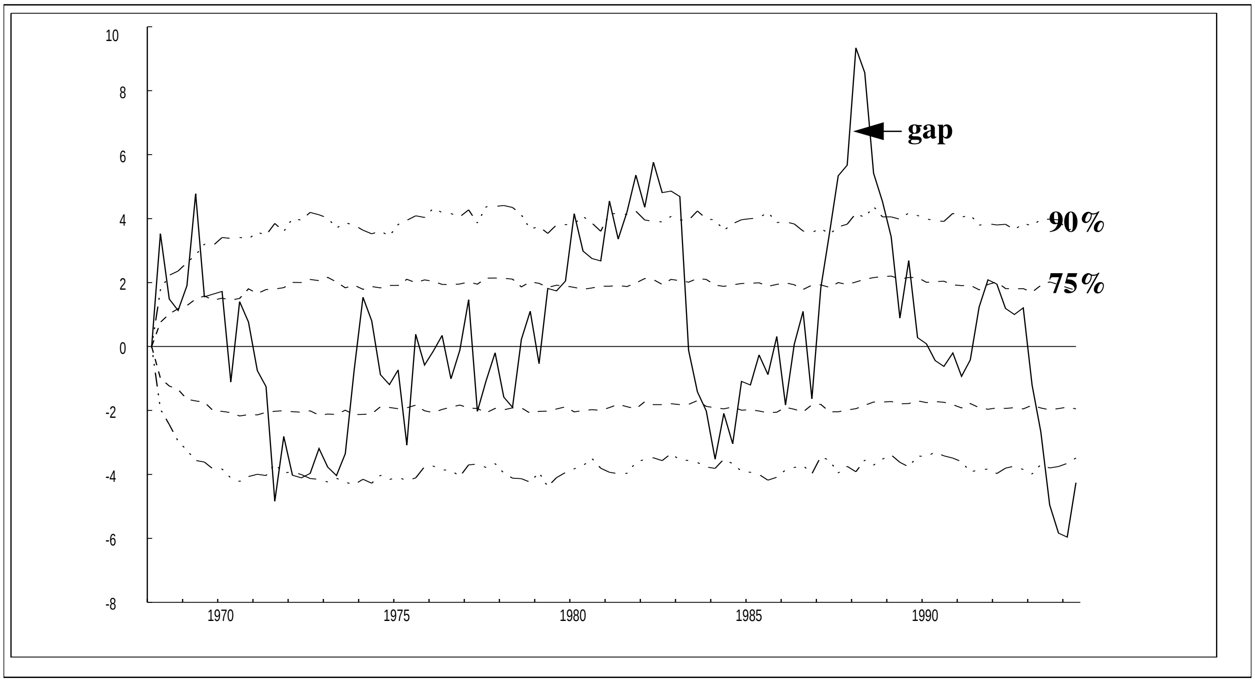


The gap between actual and potential output, expressed as a percentage of potential output, is what we define as the output gap, which is shown in Chart 4 (p. 15). There is considerable uncertainty surrounding the estimation of the output gap as illustrated by the fact that there are few periods of statistically significant excess demand (actual output above potential) or excess supply (negative gaps) when the conventional 90 per cent confidence interval is used. This is why we also show a 67 per cent confidence interval.

Although the output gap fluctuates markedly (as does Mexican output), there are substantial episodes of excess demand and excess supply . In particular , note the persistent excess demand of the late 1970s and the early 1980s, which undoubtedly contributed to the acceleration of inflation during that period (inflation is shown in Chart A-4 of Appendix 1). These excess demand gaps may reflect the expansionary fiscal and monetary policies implemented in Mexico after abandonment of the 1977 stabilization program of the International

Monetary Fund. After a period of excess supply , around 1983-85, large excess demand reemerged around 1986-87. This again, probably reflects the easing of fiscal and monetary policies. Inflation accelerated during those years. Finally , note that since 1992 a large excess supply gap has appeared in Mexico. This can be attributed to the tight financial policies followed during this period, which also saw a deceleration of inflation.

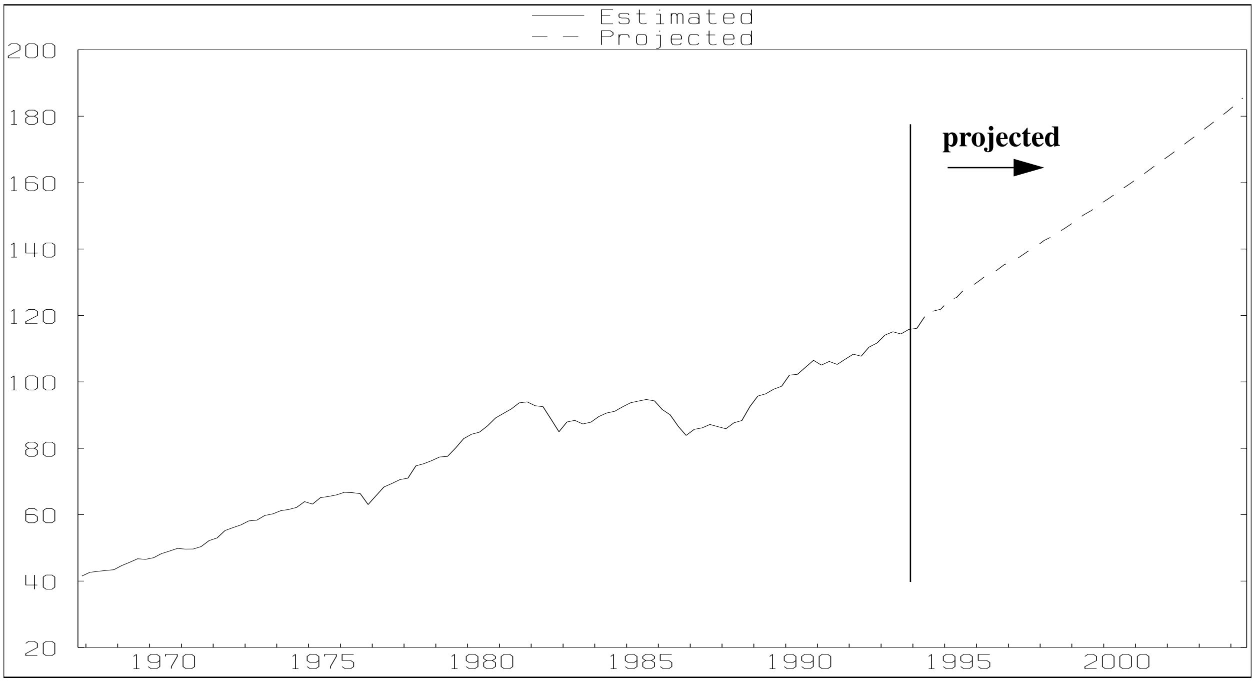
Chart 4: Output gap
(actual minus potential output in per cent of potential output)



4.4 Projecting potential output

We can project the level of Mexico’ s potential output by adding the effect of past supply shocks to the deterministic trend in industrial production. This is done in Chart 5 (p. 16), which shows estimated and projected potential output for Mexico. Note that projected potential output tends toward the estimated deterministic trend in industrial production as the effect of past supply shocks subsides.

Chart 5: Estimated and projected potential output



5 Conclusions

In this paper, we show how potential output can be estimated and projected using an approach derived from the SVAR methodology, which has many advantages over other approaches. Applying this method to the specific case of the Mexican economy, we find that world oil shocks have been an important source of both actual and potential output fluctuations over a sample period extending from 1965 to 1994. However, we also find occurrences of important gaps between actual and potential output.

Because of limitations in the data on the Mexican economy, we confined ourselves to a three-variable VAR representation model approach. Models including more variables could be used to identify other types of shocks, which could reduce the uncertainty surrounding the estimation of potential output and the output gap. We intend to look at such models to estimate potential output in other countries.

Appendix 1
Charts of the series

Chart A-1: Price of West Texas intermediate crude oil

(deflated by the U.S. CPI)

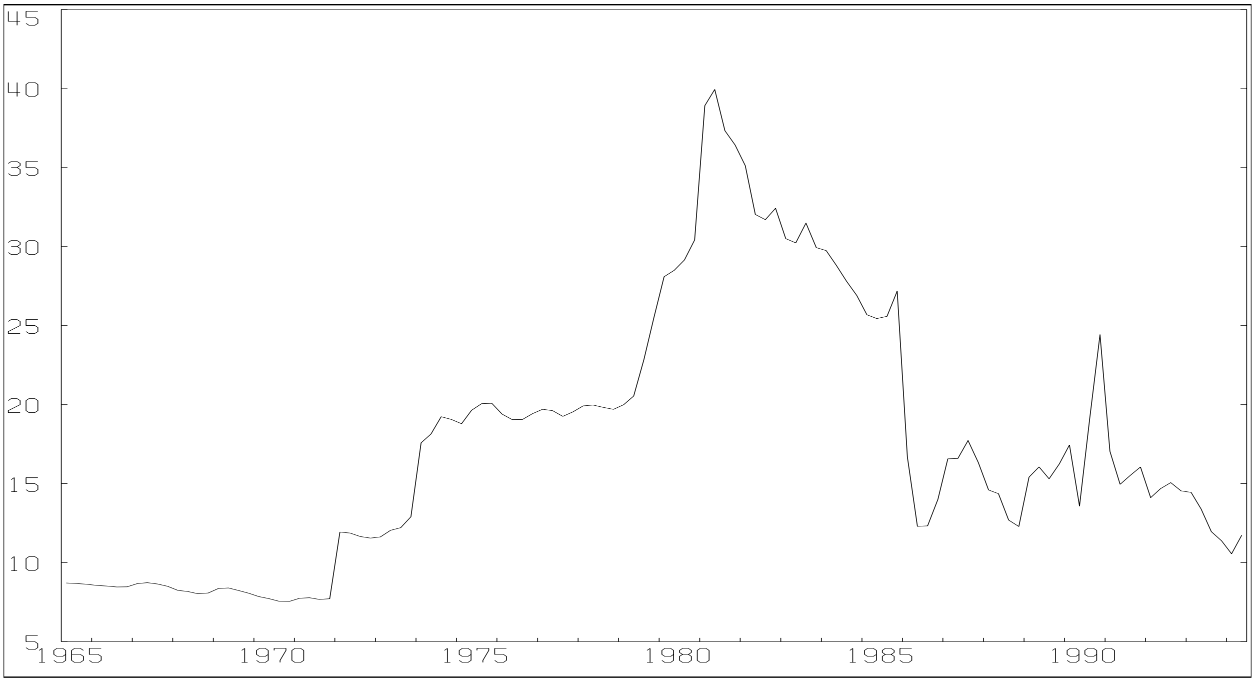


Chart A-2: Industrial production

(year-over-year growth rate)

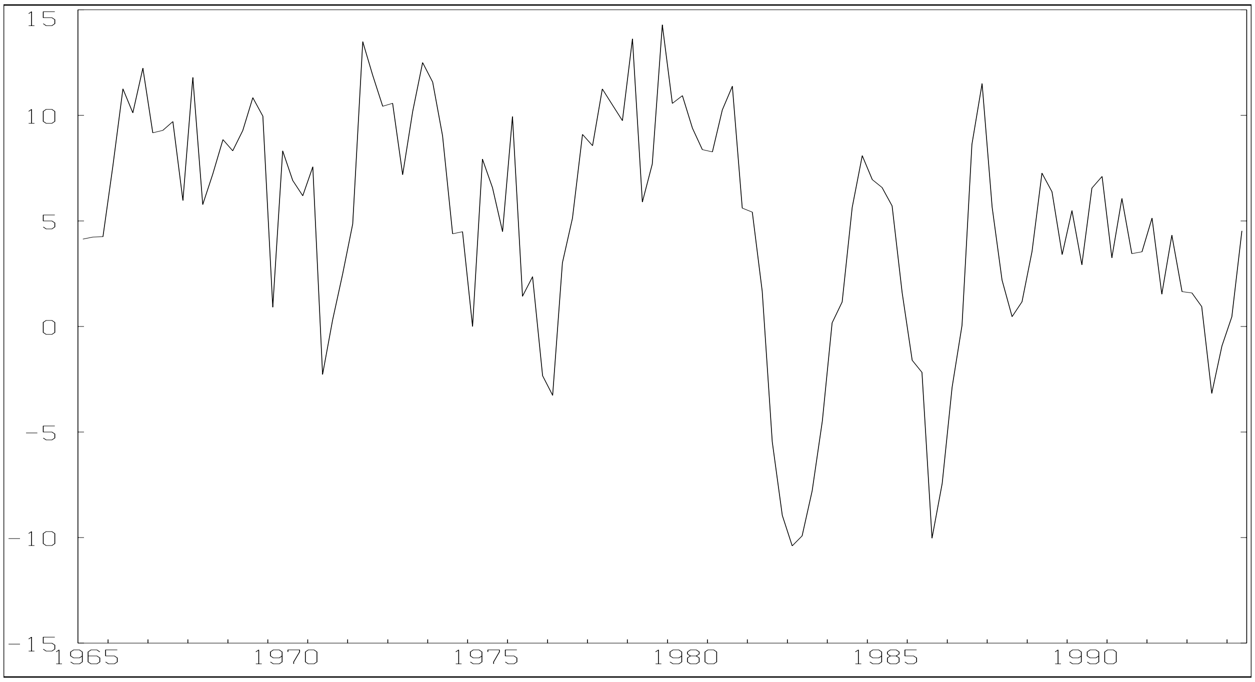


Chart A-3: Monetary base
(year -over -year growth rate)

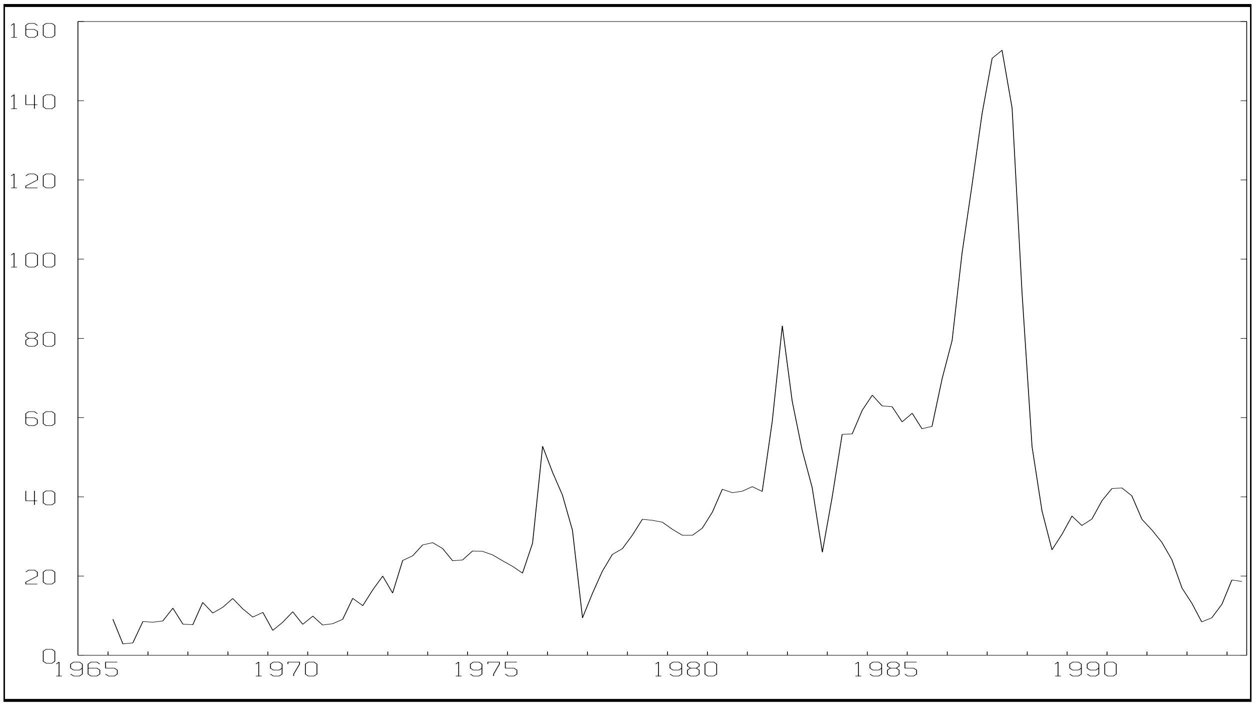
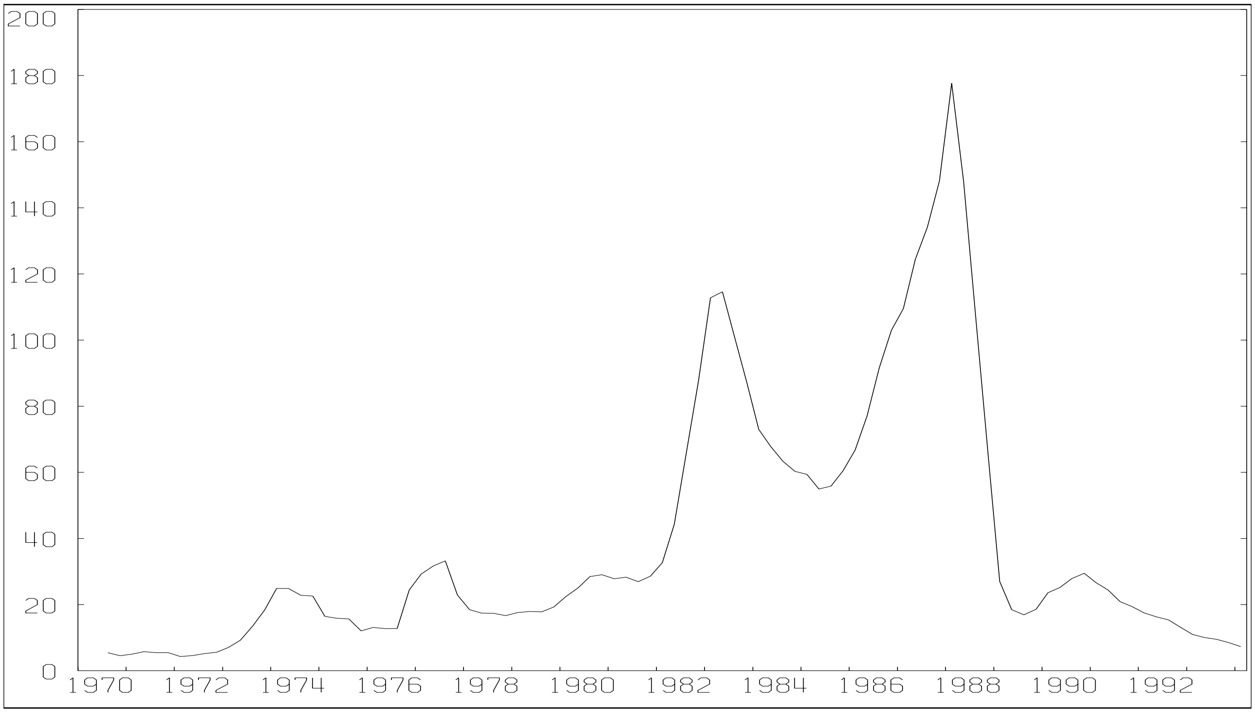


Chart A-4: Consumer prices
(year -over -year growth rate)



Appendix 2
Unit-root and cointegration tests

Table A-1 shows the results of the augmented Dickey-Fuller (Dickey and Fuller 1979), Phillips and Perron (1988) and Schmidt and Phillips (1992) tests of the null hypothesis of nonstationarity of the price of oil, industrial production and the monetary base. The results are unambiguous and clearly support the hypothesis that these series are stationary in first differences.

Table A-1: Unit-root tests
(sample: 1965Q2-1994Q2)

Series (in logarithms)	**Test statistics** [a]			
	ADF [b]	**PP (l=4)** [c]	**PP (l=12)**	**SP** [b]
Industrial production (level)	1.65	4.18	3.92	3.31
Industrial production (first difference)	**4.46**	**121.36**	**112.72**	**94.18**
Monetary base (level)	2.19	3.22	3.79	0.44
Monetary base (first difference)	**3.01**	**44.12**	**57.33**	**37.94**
Oil prices (level)	0.76	2.69	3.01	3.80
Oil prices (first difference)	**9.0**	**89.45**	**114.05**	**104.04**

a. The tests presented here allow for the presence of a linear trend in the series in level form, but assume that there is no deterministic trend in the differenced series. The critical limits at a 5 per cent significance level of the ADF and the PP tests are 3.45 and 20.7, respectively , for the tests that include a linear trend, and 2.89 and 13.7, respectively , for the tests that do not include a deterministic trend. The critical limit at a 5 per cent significance level of the SP test is 18.1. Bold figures indicate that the unit-root hypothesis is rejected.

b. The number of lags for the ADF and SP tests was chosen using the recursive procedure suggested by Ng and Perron (1993).

c. The choice of the lag lengths for the PP test is related to the size of the sample according to formulas suggested by Schwert (1989).

While unit root tests suggest that the variables are nonstationary in levels, it is still possible that a stationary linear combination of these levels could be found. To test for this, we used the method proposed by Johansen (1988) and applied by Johansen and Juselius (1990). The results of the MV and TR tests presented in Table A-1 support the hypothesis that there is no cointegrating relationship between the variables considered in this paper. Note that we also applied the single-equation procedure suggested by Engle and Granger (1987) but could not find evidence of cointegration using that approach either (these results are not presented here).

Table A-2: Cointegrating rank statistics
(sample: 1965Q2 to 1994Q2)

	MV	**TR**
H_0: $r = 0$	15.1	26.3
95% critical value	20.9	29.7

Note: The number of lags to be included in the vector error-correction model (10) was selected according to a general-to-specific strategy on the basis of an LR test using a 10 per cent critical value.

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