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An Innovation-Accounting Approach to External Shocks in a Small Economy with Fixed Exchange Rates: Ireland and the United Kingdom, 1959-1978

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1. Introduction

This paper presents an empirical analysis of the responses of a small economy, in this case the Republic of Ireland, to external macro-economic disturbances originating in a large economy, the United Kingdom, under a regime of fixed exchange rates. Using the innovation-accounting techniques developed by Sim's (1980), an eight variable model consisting of quarterly observations on the money supply, interest rate, price level and real income/output for each country is estimated as an unconstrained vector autoregression (VAR) over 1959 (1) to 1978 (4). The moving average representation of the VAR is then used to trace out impulse responses for each variable to one-period shocks in each U.K. variable, with the Irish responses being taken as indicators of the strength and direction of the domestic economy's reaction to external disturbances. In addition to the impulse responses the moving average representation is used to decompose the forecast error variances into proportions attributable to each variables' innovations. This variance decomposition may then be used as a guide to the exogeneity of each variable in the system.

Innovation-accounting techniques are useful in considering problems such as the international transmission of economic disturbances because they permit the data to yield systematic information from a minimum set of model-identifying, or a priori, restrictions. Although the VAR system may be thought of as the reduced form of a structural model it is not possible to identify any particular structure from the estimated VAR. That is, innovation-accounting does not test one theory,
or structure, against another in the sense that a given structure may be identified from the reduced form. Alternative models, however, suggest empirical regularities in the data such as the manner in which a certain variable may respond to changes in another variable so that innovation-accounting results may be interpreted by referring to the economic structure, or structures, which they are consistent. The techniques used in this paper may therefore be considered as an approach which simply allows the data to indicate which set of structural assumptions, if any, best approximate the empirical system under investigation.

At the risk of pre-empting the conclusions, the paper provides evidence that external monetary disturbances manifest themselves only in the nominal levels of domestic prices and interest rates while real disturbances, such as an increase in foreign real income, have no effect on domestic production. Specifically, the results suggest that the Irish Consumer Price Index and long term bond rate produce significant positive responses to U.K. money supply shocks and that Irish industrial production is invariant to one-period changes in British GDP. Further, the Irish Price level appears to be unresponsive to shocks in the U.K. price level whereas the Irish interest rate is strongly related to movements in the U.K. interest rate.

2. Vector Autoregressions

To illustrate Sims' (1980) innovation-accounting techniques consider the following VAR system,

\[ F(L)Y_t = u_t \quad (1) \]

where \( Y \) is an \( nx1 \) vector of endogenous variables, \( u \) is an \( nx1 \) vector of white noise processes and \( F(L) \) is an \( nxn \) matrix of polynomials in
the backward shift operator $L$. The vector $u$ contains the innovations in the $Y$'s defined as that part of each variable which cannot be predicted from the past history of the endogenous variables. If $F(L)$ is normalised so that the first entry of each polynomial in the diagonal is unity then converting (1) to the moving average representation gives,

$$Y_t = [F(L)]^{-1}u_t = \sum_{i=0}^{\infty} C_i u_{t-i}$$

(2)

where $C_0$ is an identity matrix so that a unit shock to the $k$th component of $u_t$ produces a unit response to the $k$th component of $Y_t$. The response of $Y$ at time $t+j$ to a shock in the $k$th component of $u_t$ is given by

$$Y_{t+j} = C_j u_t$$

so that the columns of $C_j$ give the impulse responses of each $Y$ at time $t+j$ to shocks in $u$ at time $t$.

Prior to computing the impulse responses it is often considered desirable to orthogonalise the innovations. If this is not done then shocks to the $k$th component of $u_t$ will only induce contemporaneous responses to the $k$th component of $Y$. Orthogonalising the innovations implies a specific order for the variables in $Y$. If, for example, $Y' = (Y_1', Y_2', \ldots, Y_n')$ and the variables are ordered $1, 2, \ldots, n$ then shocks to $Y_1'$ innovations will induce contemporaneous responses in all components of $Y$, while shocks to $Y_2'$ innovations will induce contemporaneous responses in $Y_2', \ldots, Y_n'$ but not in $Y_1'$. Non-orthogonalisation implies that shocks to the $Y_i'$ innovations will induce contemporaneous responses in $Y_i'$ only. To orthogonalise the innovations let $u_t = Sv_t$, where $v_t$ is a vector of orthogonal random variables such that $vv' = I$ and the matrix $S$ is defined by $SS' = T$, the covariance matrix of $u_t$. Although there is more than one factorization of the covariance matrix $T$ into $SS'$ the computation method
uses the Choleski decomposition, in which $S$ is lower triangular.\textsuperscript{2} Equation (2) may therefore be re-expressed in terms of the orthogonalised innovations. That is,
\begin{equation}
Y_t = \sum_{0}^{\infty} C_S Y_{t-i}
\end{equation}
where the columns of $C_S$ give the impulse responses of each $Y$ at time $t-j$ to shocks to the orthogonal innovations at time $t$.

Each country is modelled by four key macro-economic variables. These are, the long-term government bond rate ($R$), the nominal money stock ($M$), the nominal price level ($P$) and a measure of real income or domestic output. Letting U.K. denote the United Kingdom and IR denote Ireland then the eight variables used are RUK, RIR, MUK, MIR, PUK, PIR, YUK and YIR, where RUK is the British interest rate and RIR is the Irish interest rate etc. MUK is defined as the broad money supply, or Sterling M3; MIR is the domestic credit component of the Irish money supply (the appropriate policy variable in a small economy); PUK is the Retail Price Index (1975=100), PIR is the Consumer Price Index (1975=0); YUK is Gross Domestic Product at constant 1975 prices and YIR is an index of industrial production based on 1975=100.\textsuperscript{3} A full description of the data and sources is given in the Appendix.

An important decision in estimating VARs is the choice of lag length. Letting $n$ be the number of endogenous variables in the system, $d$ be the deterministic components (seasonals etc.) and $m$ be the lag length the total number of coefficients to be estimated is given by $n(nm+d)$. Increasing $m$ obviously leads to an increase in the number of coefficients and to a loss of degrees of freedom given a fixed data period. The lag length was therefore set at $m=2$, or six months, and
the deterministic components used were a constant, trend and three seasonal dummies. All variables were logged, except for RUK and RIR, and the system estimated over the period 1959 (3) to 1978 (4).

Summary statistics for the VAR are given in Tables 1 and 2. Table 1 gives critical levels for F-tests of the hypothesis that all lags on the indicated RHS variables are zero, where the critical level is defined as the significance level at which the null hypothesis is just rejected. Table 2 presents contemporaneous correlations between the process. Given that theoretical considerations suggest placing the four U.K. variables first in the ordering it is useful to consider the first four rows and last four columns of Table 2 as indicators for the appropriate orderings within each subset of variables. The relatively low values of these correlations suggests that the results to be presented below may not be especially sensitive to the ordering used. Experimentation with different orderings confirmed this suggestion and the ordering selected was (RUK, MUK, PUK, YUK, RIR, MIR, PIR, YIR).

3. Impulse Responses

To compute the impulse responses a shock was administered to each U.K. variable. The size of the shock was set at one standard deviation of the RUK, MUK, PUK, and YUK innovations and the responses of each variable in the system were scaled by the standard deviation of its own innovations. Figures 1a to 1d give the responses of both interest rates and prices to shocks in MUK, RUK and PUK. The solid line in Figure 1a, for example shows the response of RUK to a shock in MUK relative to the degree of variation in the former's innovations while
while the dashed line gives equivalent information for RIR's responses.

Figures la and lb suggest that the responses of PIR and RIR to external money supply shocks closely reflect those of their U.K. counterparts with similar turning points in each pair of series. The positive interest rate responses, figure la, are at variance with the traditional IS-LM approach but can be reconciled with the concept of efficient markets in which expectations are formed rationally. Further, it is of interest to note that Burbidge and Harrison (1984) report similar patterns for the responses of Canadian and United States interest rates to one period shocks in the U.S. money supply.

Figure lb shows the responses of both price levels to a shock in MUK. It is clear that the responses of PIR, relative to the variation in its own innovations, are much smaller than those of PUK indicating that arbitrage in the commodity markets may be a less viable assumption than in the asset markets. Figures 1c and 1d suggest a similar conclusion. The manner in which the responses of RIR to a shock in RUK mirror the latter's own responses is exactly what the small economy model predicts if domestic and foreign assets are close substitutes. The divergence between the responses of PIR and PUK to shocks in the latter, on the other hand, appears to be greater than what might be expected if commodity arbitrage was the principal channel by which external price disturbances affect the small economy.

The failure to detect a significant degree of price arbitrage is consistent with the results reported by Cassese and Lothian (1982) for seven countries, excluding Ireland. Although no firm conclusions can be drawn on the manner by which price disturbances are transmitted
order fixed exchange rates, it is possible that interaction between the domestic money supply and deficits/surpluses in the balance of payments plays a central role. For example, Parkin (1977) suggests that a rise in the 'world' price level, or PUK in this case, changes the terms of trade in favour of the small country resulting in a current account surplus which exerts upward pressure on the price level via its impact on the domestic money supply. However, to disentangle these mechanisms requires that changes in the domestic money stock be decomposed into variations due to changes in domestic credit and net foreign assets and that the latter be further subdivided into current account and capital account effects. Such an exercise is beyond the scope of the present paper.

An alternative explanation of figures 1b is to consider the existence of significant non-traded goods sectors in both economies with national price levels being approximated by weighted averages of the prices of traded and non-traded goods. A shock to MUK, for example, might then lead to PUK rising at a faster rate than PIR with the divergence depending upon the weight given to non-traded goods in the determination of the Irish price index.

Although figure 1 provides useful information on the timing of each pair of responses it does not tell us anything about their statistical significance. Figures 2a to 2d reproduce the four Irish responses in figure 1 together with a set of one-standard error bands. The dashed lines in figure 2 are the responses (solid lines) plus or minus one standard error of the posterior distribution of the orthogonalised responses. 5 Figures 2a and 2c suggest significant
responses of RIR to external shocks for about ten periods while 2b indicates the same is true for the responses of PIR to shocks in MUK. Figure 2d, on the other hand, shows that apart from the first few periods there is little significance in the response of PIR to shocks in PUK.

Turning to the impact of real disturbances, figures 3a and 3b give the responses of PIR and YIR to a one period shock in YUK. As YUK is real GDP those responses may be interpreted as the Irish economy's reaction to an external demand shock. Compared to its response to a shock in MUK, the responses of PIR to YUK are relatively weak and insignificant suggesting that monetary rather than real factors are the most important external influence on the Irish price level. Further, apart from the first few periods the responses of YIR to YUK are not only insignificant but also have the wrong sign. One possible explanation of figure 3b is to consider the rise in YUK as a demand shock to the traded goods sector of the Irish economy. Any subsequent rise in the relative price of traded goods may therefore lead to a movement along the production possibility curve with production of traded goods rising at the expense of a decline in non-traded goods. That is, a shock to YUK may result in a change in the composition rather than the level of YIR. The problem with this interpretation is that it requires the domestic economy to be at full employment in the sense that increased production in one sector requires a decline in resource use in the other. As the Irish economy was most certainly not at full employment over the sample period it is difficult to reconcile the data with structural models, such as the IS-LM 'unemployment equilibrium', which treat domestic output as being primarily demand determined.
Additional evidence is provided by Table 3 which presents a decomposition of the forecast errors in each of the endogenous variables. Assuming a zero value for the expectation, at time \( t \), of \( u_{t+j} \) means that the error in the \( j \)th step-ahead forecast of the \( Y \)'s can be expressed as,

\[
\sum_{i=0}^{j-1} C_{i} u_{t+j-i} = \sum_{i=0}^{j-1} C_{i} S_{v_{t+j-i}}
\]

where, as before, the \( C \)'s are the coefficients in the moving average representation, \( SS' \) is a decomposition of the covariance matrix of \( u \) and the \( v \)'s are orthogonalised innovations. The variance of the forecast error may then be apportioned among the \( n \) components of \( Y \). Table 3 therefore shows that 49.1 per cent of the 12 step-ahead forecast error variance in RUK may be attributed to its own innovations, 22.1 per cent to MUK innovations and 1.7 per cent to PUK innovations etc. The first column gives the variable, the second gives the step at which the variance is decomposed and the third gives the standard error of the forecast.

The greater the proportion of any variable's forecast error variance which can be explained by its own innovations the more likely it is that that variable should be treated as exogenous. Likewise if one variable is dominant in accounting for the forecast error variance in another variable then the former may exert a causal influence on the latter. The results from Table 3 therefore confirm our interpretation of the impulse responses presented above. That is, RUK clearly exerts a strong influence on RIR as does MUK on both PUK and PIR. YUK and PUK on the other hand, have minor roles in explaining the variance of the forecast errors in YIR and PIR respectively.
The overall impact of the U.K. variables on the Irish economy is neatly summarised by the last four rows and first four columns (i.e. RUK to MUK) of Table 3 from which it is clear that the influence of RUK and MUK significantly exceeds that of PUK and YUK. Finally, to test the sensitivity of these results to the orthogonalisation, the variance decompositions were computed using the ordering (YUK, PUK, MUK, RUK, YIR, PIR, MIR, RIR) which keeps the four U.K. variables first but reverses the order within each subset. The results from this ordering are given in Table 4 and do not indicate any modification to the interpretations presented above. That is, RUK is still the dominant influence on RIR; MUK plays a significant role in explaining the error variance of both price levels and YIR is independent of external influences.

4. Conclusions

The purpose of this paper was to investigate the manner in which a small economy responds to externally generated macro-economic disturbances under fixed exchange rates. Using Ireland as an example of a small economy the evidence suggests that it is the U.K. money supply, rather than the price level, which plays the dominant role in explaining PIR and that Irish industrial output is unresponsive to external demand shocks.

The extent to which these results can be generalised depends upon how representative Ireland is of the typical small open economy. At least four features of the Irish economy suggest that it is an excellent approximation to the type of small economy discussed in the theoretical literature. First the Irish pound was held at one to one parity with Sterling from the foundation of the state in the early twenties to the second quarter of 1979. Second the UK accounted for more than 50 per cent
of Irish exports and about 45-50 per cent of imports over the sample period. Third, Irish GDP is about 4 per cent of U.K. GDP and fourth, the period used is characterised by a high degree of free trade in commodities and by unrestricted movement of both capital and labour. Given these characteristics Ireland appears to be a classical small open economy.

Finally, although these results conflict with certain aspects of the popular pedagogy it is important to note that they are broadly consistent with evidence reported elsewhere. For example, Burbidge and Harrison (1984) find a much stronger relationship between the Canadian and U.S. monetary sectors than between the corresponding real sectors while Cassese and Lothian (1982) present evidence "inconsistent with an [inflation] adjustment mechanism that operates exclusively via price arbitrage" (p. 21).
Table 1. Critical Levels of F-Statistics on RHS Variables

<table>
<thead>
<tr>
<th>RHS Variable</th>
<th>RUK</th>
<th>MUK</th>
<th>PUK</th>
<th>YUK</th>
<th>RIR</th>
<th>MIR</th>
<th>PIR</th>
<th>YIR</th>
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<td>.351</td>
<td>.215</td>
<td>.377</td>
<td>*</td>
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<td>*</td>
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<td>.555</td>
<td>.084</td>
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Note: * indicates less than .01
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Figure 1. Interest Rate and Price Level Responses to Shocks in,

(a) MUK

- RUK
- RIR

(b) MUK

- PUK
- PIR

(c) RUK

- RUK
- RIR

(d) PUK

- PUK
- PIR
Figure 2. Responses of RIR and PIR, with +/- one SB Bands, to Shocks in...

(a) MUK
- RIR
- +/- SD

(b) MUK
- PIR
- +/- SD

(c) RUK
- RIR
- +/- SD

(d) PUK
- PIR
- +/- SD
Figure 3  Responses of PIR and YIR, with +/− one SD Bands, to shocks in YUK
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Footnotes

1. The methodology of this paper is similar to that of Burbidge and Harrison (1984) who present a similar analysis of Canadian and United States data for the flexible exchange period 1971-1982.

2. The RATS time series package was used for all computations. See Doan and Litterman (1981).

3. Irish data sources do not include a quarterly series on GDP.

4. A sequence of likelihood ratio tests were performed for different values of m. Starting at m=4 the data accepted the restriction to m=3 and m=2.

5. The standard errors were computed by taking 100 draws from the posterior distribution. See Doan and Litterman (1981) ch. 12.
References


Data and Sources


PIR Irish Consumer Price Index, \textit{Main Economic Indicators} (OECD) 1975=100.

YIR Index of Industrial Production, \textit{Main Economic Indicators} (OECD) 1975=100.