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International Transmissions to Australia: The Roles of the US and Euro Area[*]

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Abstract

This paper examines the influences of the two largest developed economies, namely the US and the Euro area, on Australia as an exemplar of a small open economy. To do so, we specify and estimate a structural VAR with bilateral linkages between the two large economies, and allow shocks orginating there to affect the Australian economy. More specifically, we show the role of foreign demand shocks, the differential effects of US or European sourced inflation and interest rate shocks on the Australian economy, and the relative unimportance of these foreign shocks to variations in the value of the Australian currency.

JEL Categories: F41,C51,C32

Keywords: VAR, open economy, Australia

1 Introduction

The existing empirical SVAR literature for Australia typically represents the source of international effects as either the US (Dungey and Pagan, 2000, 2009; Buncic and Melecky, 2008; Voss and Willard, 2009; Leu 2011), a single conglomerate (Claus, Dungey and Fry, 2008; Leu and Sheen, 2011, Langcake and Robinson, 2013), different conglomorates for interest rates compared with output and inflation (Nimark, 2009; Jääskelä and Nimark, 2011) or, less frequently, ignores the issue by treating the economy as closed (Moreno, 1992). The rationale is to allow the simple implementation of the small open economy assumption whereby there are no feedbacks from Australia to the rest of the world, and the dynamics of interactions in the rest of the world are essentially unmodelled. In reality, shocks sourced from one trading partner may have a substantially different impact on the economy than from another - for example shocks to US final demand may cause significantly more concern amongst financial analysts than those in Europe. However, both the US and the Euro area represent important trading partners for Australia - only relatively recently has China attained the status of Australia's second largest trading partner.[1] In any case, Lee, Huh and Harris (2003) find that the importance of the US and Japan for the business cycle in Australia does not reflect their relative roles in respect of Australian exports, suggesting that different transmission mechanisms may apply for shocks originating in different foreign regions.

In this paper we empirically estimate the effects of international shocks originating from the US or Euro area on Australia, accounting for the fact that these large open economies interact, that there are long and short-term relationships within and between the macroeconomic conditions in all three economies and identifying the sources of both transitory and permanent shocks.[2] Clearly shocks to both the US and Euro area economies directly affect the Australian economy. However, the interactions between these two large economic regions result in both direct and indirect linkages between the international sources and the Australian economy. Our analysis provide a reassessment of the mixed results on the importance of aggregate demand in driving Australian output. Recently, Leu (2011) supported the dominance of aggregate supply shocks, a view previously held in Moreno (1992) based on a closed economy specification. Other literature supports aggregate demand shocks as a driver, including Dungey and Pagan (2000) and Buncic and Melecky (2008), with the latter

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[1] The effects of China on the Australian economy are discussed in Plumb, Kent and Bishop (2013), and Dungey, Fry-McKibbin and Linehan (2013), and will be a focus of future research.

[2] The Euro Area in this study comprises those countries formally part of the European Monetary Union who have adopted the euro as their currency as at 2009 in line with the dataset compiled for the Euro Area in Anderson, Dungey, Osborn and Vahid (2011). It comprises France, Germany, Austria, the Netherlands, Italy, Belgium, Luxemburg, Spain, Portugal, Ireland.

particularly indicating a strong role for foreign sourced demand shocks. We also closely examine the response in Australian inflation and monetary policy to shocks in inflation and monetary policy sourced from two distinct international economies - building on the small number of results which suggest that these effects may not be particularly important. Finally, we analyse the driving forces for the Australian dollar TWI (trade-weighted exchange rate index) in a model which contains a greater proportion of our trading partners than the existing SVAR evidence from Voss and Willard (2009) who find that variation in the exchange rate is driven primarily by Australian output shocks, with interest rate and inflation components relatively irrelevant.

We build on the identifying framework of Dungey and Osborn (2013) to model the interactions of large open economies, and use a benchmark specification of the Australian economy from Dungey and Pagan (2000, 2009), incorporating potential cointegrating relationships in the manner specified in Pagan and Pesaran (2008) which is more clearly explained in Fisher and Huh (2012). Typically, the variables included in the international sector of SVAR models of Australia are limited in number, and do not interact with each other – for example the US is represented by inflation and interest rates in Leu (2011) and by GDP in Dungey and Pagan (2009). Other papers do have specifications including at least foreign output, inflation and interest rates; see Langcake and Robinson (2013), Buncic and Melecky (2008), Dungey and Pagan (2000) or Dungey and Fry (2003), but capturing the interactions between foreign economies[3] is limited to the unobserved component approaches of Dungey, Claus and Fry (2008) and Leu and Sheen (2011).

The consequence of our framework is a much richer characterisation of the transmission of international shocks to the Australian economy. We show that permanent output shocks originating in the US have a far greater effect on Australian output than those from the Euro area. Inflation shocks from both areas increase Australian inflation. However, the response of monetary authorities in the US to inflation shocks originating in the US is faster than that of the Euro area authorities to Euro area sourced shocks. This is reflected in a smaller Australian response to the threat of imported inflation from US shocks than for those from the Euro area. Presumably this reflects that the Australian central bank feels that temporary deviations in US inflation are less likely to be sustained than in the Euro area.

The paper proceeds as follows. Section 2 outlines the modelling framework and shows

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[3] The Dungey and Pagan (2000) model is extended by Dungey and Fry (2003) to include variables for both the US and Japan, but they assume that all US variables are exogenous to those of Japan, with both countries exogenous to Australia.

particularly how we identify the problem for a small open economy (Australia) influenced by two interdependent large open economies (the US and Euro area). We describe the data and cointegrating relationships in Section 3 and Section 4 presents the formal results including impulse response functions and historical decompositions. Section 5 concludes.

2 Econometric Framework

Dungey and Pagan (2000, 2009) develop a macroeconomic model for Australia as a small open economy, representing foreign influences through the inclusion of (exogenous) US variables. From an econometric perspective, Dungey and Pagan (2009) explicitly recognise the mixed $I(0)$ and $I(1)$ nature of the data series employed and show how to incorporate both into an SVAR model using the insights of Pagan and Pesaran (2008). In particular, the resulting SVECM (structural vector error-correction model) imposes restrictions that recognise shocks identified as permanent have no error-correction terms. Further, both $I(1)$ and $I(0)$ variables are incorporated in the error-correction representation via the equivalent of a Bewley-transformation for the $I(0)$ variables through the creation of a pseudo-ecm term for each $I(0)$ variable.

This SVECM framework is used by Dungey and Osborn (2013) to loosen the exogeneity assumption in the context of modelling interactions between two large economies. Rather than the country-by-country identification scheme typically used in the open economy VAR literature (for example, Cushman and Zha, 1997), they propose a variable-by-variable scheme, which restricts the direction of only contemporaneous relationships between key variables for the US and Euro area.

In the light of the important bidirectional interactions between the US and the Euro area shown by Dungey and Osborn (2013), this paper investigates whether shocks originating in these two major international economies have distinctive roles for Australia. Considering the relative sizes of the economies, Australia is treated as a small open economy with no feedback to either the US or the Euro area, but variables in both of these are allowed to influence Australia, potentially in distinctive ways. The resulting framework for econometric modelling is discussed below.

2.1 Structural Error Correction Model (SVECM)

For a specific variable category i, such as interest rates, the observation vector at time t is defined as $Y_{it} = (y_{it}^{us}, y_{it}^{ea}, y_{it}^{au})'$, where the superscripts denote the country. Note that the vectors are not restricted to be of the same dimension throughout; in particular the exchange rate block includes two series, while the output block includes four measures incorporating Australian gross national expenditure (GNE) in addition to GDP (see Section 3). For a model involving n distinct variables or blocks and with h_j series in the j^{th} block (where $j = 1, 2, \ldots n$), the complete dimension of Y_t is $m \times 1$, where $m = \sum_{j=1}^{n} h_j$, and

$$Y_t = \begin{bmatrix} Y_{1,t} \\ Y_{2,t} \\ \vdots \\ Y_{n,t} \end{bmatrix}. \tag{1}$$

The relationship among macroeconomic variables, some of which have $I(1)$ properties with potential cointegrating vectors, can be modelled using a SVECM representation with intercept terms supressed for ease of exposition

$$B(L)\Delta Y_t = \Pi Y_{t-1} + U_t \tag{2}$$

where Δ is the difference operator, $B(L) = B_0 - B_1 L - \ldots B_p L^p$ and Π are $m \times m$ coefficient matrices while U_t is $m \times 1$ zero mean uncorrelated disturbance vector, consisting of n blocks, $U_{it} (i = 1, 2, \ldots, n)$ partitioned as for Y_t in (1). We assume that sufficient restrictions are imposed on the parameters of (2) such that the disturbance vector U_t is orthogonal. The restrictions imposed consist of those arising from cointegration, conventional short-run restrictions reflecting the nature of interactions across variable blocks, and cross-country exogeneity and contemporaneous causality restrictions. The next two subsections outine the nature of these restrictions, with details of the implementation discussed in the following section.

2.2 Permanent and Transitory Shocks

The matrix Π in (2) is conventionally written as $\Pi = \alpha\beta'$ where β is a matrix of long run cointegrating relationships and α is a matrix of adjustment coefficients for $I(1)$ variables together with aggregate effects for $I(0)$ variables. If there are r cointegrating vectors both α and β are $(m \times r)$ matrices of rank r, while Y_t is subject to $(m - r)$ permanent shocks and r transitory shocks.

Pagan and Pesaran (2008) show that $I(1)$ variables that are the sources of the $m - r$ permanent shocks of the system do not contribute to long-run adjustment. In other words, such variables drive the long-run trends, so that the error-correction coefficients associated with cointegrating relationships should be set to zero in equations for variables that give rise to permanent shocks. One example is an $I(1)$ variable that is not cointegrated with other variables, and hence is included in the model only in difference form. More generally, however, the variables driving permanent shocks can enter cointegrating relationships but do not themselves react to the long-run disequilibrium. As discussed by Fisher and Huh (2012), the Pagan-Pesaran identification of permanent shocks is attractive in that the sources of these shocks are specified explicitly; consequently we follow this methodology and specify the $m - r$ structural equations that are subject to permanent shocks.

The r transitory shocks are then of two types. Firstly, there are transitory shocks associated with cointegrating relationships among the $I(1)$ variables. If the m individual variables of the model include m_1 that are $I(1)$ with r_1 cointegrating relations between them, then the equations for r_1 of the $I(1)$ variables are subject to transitory shocks. These variables perform the adjustment to the long-run cointegrating relationships.

Secondly, transitory shocks may arise from equations for $I(0)$ variables. ($I(0)$ variables may also be associated with permanent shocks, they are not required to be transitory – see Fisher, Huh and Pagan (2013) – however in our application there are no permanent effects associated with shocks to $I(0)$ variables). Thus the number of transitory shocks arising from $I(0)$ variables here is given by $r_2 = r - r_1 = m - m_1$. By employing the Bewley transformation of the stationary variables, we write the dynamics of each in terms of differences and (one-period) lagged levels, with the latter giving rise to a pseudo-cointegrating vector (Dungey and Pagan, 2009). In particular, the equation for each $I(0)$ variable has a corresponding column of β, with this pseudo-cointegrating vector containing a unit element relating to its own lag and all other elements of the column being zero.

Consequently three types of variables are distinguished in our SVECM, with each type having a distinctive treatment in terms of α and β. Firstly, $m - r = m_1 - r_1$ nonstationary $I(1)$ variables are identified as the sources of the permanent shocks; the equations for these variables do not include any error-correction terms. Secondly, the remaining r_1 $I(1)$ variables perform the adjustment to the long-run cointegrating relationships. The equations for these variables therefore include adjustment coefficients to the cointegrating relationships (as well as to pseudo-cointegrating relationships) and are subject to transitory shocks. Finally, there are r_2 stationary variables, whose equations are written in error-correction form through the inclusion of pseudo-cointegrating vectors with associated adjustment coefficients.

2.3 Contemporaneous Causality and Exogeneity Restrictions

The vector Y_t of (1) consists of four blocks, with

$$Y_t = [x'_t, \pi'_t, r'_t, q'_t]' \tag{3}$$

with x_t, π_t, r_t and q_t being vectors of output, inflation, interest rate and real exchange rate series, respectively. The restrictions imposed include conventional contemporaneous ordering assumptions across the four blocks, and hence the partitioned matrix B_0, with partitions conformable to Y_t of (3), has the form

$$B_0 = \begin{bmatrix} B_{11}^{(0)} & 0 & 0 & 0 \\ B_{21}^{(0)} & B_{22}^{(0)} & 0 & 0 \\ B_{31}^{(0)} & B_{32}^{(0)} & B_{33}^{(0)} & 0 \\ B_{41}^{(0)} & B_{42}^{(0)} & B_{43}^{(0)} & B_{44}^{(0)} \end{bmatrix}$$

with unit diagonal elements in each $B_{ii}^{(0)}$ $(i = 1, 2, 3, 4)$.

Although additional restrictions are required for identification, there is no requirement in this set-up that the same cross-economy contemporaneous causality assumption needs to be made within each variable block. For example, the US may be considered causally prior to the Euro area for output but the reverse assumption could be made for inflation. Although Dungey and Osborn (2013) entertain the latter possibility in their model, they find this does not substantively affect the results, and hence we adopt their baseline case with the US causally prior to the Euro area within both the output and inflation blocks. Together with an exogeneity assumption for Australia in respect of both of these large economies, $B_{11}^{(0)}$ and $B_{22}^{(0)}$ are both lower triangular. However, bilateral dynamic interactions are permitted for the large economies, so that $B_{11}^{(\ell)}$ has the form

$$B_{11}^{(\ell)} = \begin{bmatrix} b_{11}^{(\ell)} & b_{12}^{(\ell)} & 0 \\ b_{21}^{(\ell)} & b_{22}^{(\ell)} & 0 \\ b_{31}^{(\ell)} & b_{32}^{(\ell)} & b_{33}^{(\ell)} \end{bmatrix} \tag{4}$$

with an analogous form for $B_{22}^{(\ell)}$. Although this discussion implicitly assumes that the output and inflation blocks each include three vaiables (one for each economy), it readily extends to different dimensions.

As discussed in the next section, and based on economic considerations, additional restrictions are imposed on the sub-matrices $B_{33}^{(\ell)}$ and $B_{44}^{(\ell)}$, for $\ell = 0$ and $\ell > 0$, namely in the interest rate and exchange rate blocks. Indeed, as in Dungey and Pagan (2009) and Dungey and Osborn (2013), we impose additional restrictions in other sub-matrices (see subsection 3.2 and Section I of the Appendix), for coherence with economic arguments. The resulting model therefore imposes restrictions based on well-grounded economic arguments, but the specification is not restricted as closely as recent New Keynesian structural models for Australia that require Bayesian estimation techniques, including Buncic and Melecky (2008), Nimark (2009) and Leu (2011), Jääskelä and Nimark (2011).

3 Data and Empirical Implementation

The sample period we analyse covers the period from the first quarter of 1984, following the float of the Australian dollar in December 1983, until the first quarter of 2008, prior to the major problems associated with the Global Financial Crisis. To our knowledge, only Langcake and Robinson (2013) have attempted to include the GFC period in an Australian analysis, and find that their model forecasts relatively poorly in the crisis period. Although Dungey and Pagan (2000, 2009) employ data from 1980, the early part of their period is not one of a fully flexible exchange rate for Australia. The 1984 starting date is used by Leu and Sheen (2011) and others when modelling Australia; it also accords well with the 1983 starting date employed by Dungey and Osborn (2013) for their US/Euro area model. Since our focus is not on modelling crises, we prefer to end the sample in 2008Q1.

Following the variable block ordering of (3), the system contains twelve endogenous variables as follows:

$$\{x^{us}, x^{ea}, gne^{au}, x^{au}, \pi^{us}, \pi^{ea}, \pi^{au}, r^{us}, r^{ea}, r^{au}, q^{ea}, q^{au}\} \tag{5}$$

representing output in the three economies and Australian GNE (the x block), inflation in three economies (π), interest rates in the three economies (r) and two real exchange rates (q). The exchange rates are q^{ea}, the real euro/US dollar rate and q^{au}, the real trade weighted value of the Australian dollar; an increase represents an appreciation of the euro or the Australian dollar, as appropriate. Output is represented by (log) real GDP, while (log) Australian GNE is also employed to represent aggregate demand since Dungey and Pagan (2000) find that it is important to separate this from GDP for Australia; GNE is assumed to be causally prior to GDP. Both π and r are in percentage terms, with inflation measured as the annual percentage change in the consumer price index and three month rates are used for interest rates. Section 2 of the Appendix provides a detailed data description, sources, plots of the series in Figure A1, together with unit root and cointegration test results in Table A1.

The output and real exchange rate series are well supported as $I(1)$ series. Although the ADF test results point to inflation being $I(1)$, the PP tests indicate stationarity[4], as anticipated by modern macroeconomic arguments. All unit root test results indicate that the interest rate series are non-stationary. Nevertheless, in line with the literature on monetary policy (see Sack and Weiland, 2000, for a review), we assume that these policy-setting rates are stationary but highly persistent; Dungey and Osborn (2013) make the same assumption in their US/Euro area model.

Our modelling approach assumes that the US, Euro area and Australian economies have similar structures, with all elements of any variable block being of the same order of integration. Consequently, our model assumes there are six $I(1)$ variables, comprising the x and q blocks of the system, and six $I(0)$ variables, comprising the π and r blocks.

3.1 Cointegration Analysis and Long-Run Restrictions

Economic arguments indicate that long-run relationships should exist amongst the six $I(1)$ variables. More specifically, international technological spillovers point to the possibility of at least one cointegrating vector between x^{us}, x^{ea} and x^{au}, while Australian GNE and output must be linked in the long-run. Although early studies, such as Bernard and Durlauf (1995), found mixed evidence that output was cointegrated internationally, recent analyses argue more strongly in favour of such cointegration. For example, Rabanal, Rubio-Ramírez and Tuesta (2011) find that a single permanent technology shock applies in a two-country model for the US and the rest of the world, while Guerron-Quintana (2013) finds a common trend important for per capita output movements across Australia and six other small open economies. In this context, Table A2 in the Appendix 1 provides the results of Johansen cointegration tests applied to the six $I(1)$ series of our model; the results in the left-hand panel include variables from both the output and exchange rate blocks, with the latter excluded from the right-hand panel.

Analysis of the six variables in a single VAR points to three cointegrating vectors, with restrictions then required for their identification. Based on the international role of the US as the largest economy in the world, we interpret two of these as long-run relationships between US output and each of the Euro area and Australia, with the relevant real exchange rate capturing the role of the external sector. The final cointegrating relationship is essentially a domestic Australian one, linking GNE and output and the real exchange rate. The implied

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[4] Our use of annual inflation induces additional persistence compared with quarterly inflation, with quarterly inflation for Australia yielding a highly significant PP test statistic of -6.76. However, the inflation series we employ for the Euro area and constructed by Anderson *et al.* (2011) are annual, which also has advantage of avoiding seasonality issues in quarterly CPI inflation.

over-identification restrictions are easily accepted in an otherwise unrestricted VECM that employs two lagged differences for all six $I(1)$ variables with a p-value of 0.555. At the same time, the right-hand column of Table A.2 shows the importance of the real exchange rate variables for cointegration, with little evidence that any such relationships exist between the variables of the output block alone.

More explicitly, and with the cointegrating vectors estimated by ordinary least squares, the three long-run relationships embedded in our model are:

(i) Between Euro area and US output, together with the bilateral real exchange rate between them; this is normalized on x^{ea}. This relationship has the same form, and similar estimated coefficients, to that in Dungey and Osborn (2013):

$$x_t^{ea} = 0.7312 x_t^{us} + 0.0415 q_t^{ea} + 7.3465 + ecm_{1,t}.$$

(ii) Between output in Australia and the US, linked using the Australian real exchange rate and normalized against x^{au}. The form is similar to that of Dungey and Pagan (2009), although we represent the external sector using the exchange rate rather than exports. The estimated relationship is:

$$x_t^{au} = 1.1374 x_t^{us} + 0.0670 q_t^{ea} + 1.6547 + ecm_{2,t}.$$

(iii) Between GNE and output in Australia, as in Dungey and Pagan (2009). This is normalized against gne_t^{au}, with estimated form:

$$gne_t^{au} = 1.0739 x_t^{au} + 0.1745 q_t^{au} - 1.8017 + ecm_{3,t}.$$

It may also be noted that although Dungey and Pagan (2009) include trends in their two cointegrating relationships (analogous to the second and third above), the rationale for these is not clear and they are not included in our specifications.

Since these six $I(1)$ variables are linked by three cointegrating vectors, the system is subject to three permanent shocks. These permanent shocks are assumed to originate from x^{us}, x^{ea} and gne^{au}, representing country-specific productivity and preference shocks. Consequently, we assume that shocks to x^{au}, q^{ea} and q^{au} are transitory and hence these variables undertake the adjustment required for the cointegrating relationships to hold. In allowing country-specific technology shocks to have permanent effects, our model differs from that of Rabanal *et al.* (2011). However, our output data do not support the presence of only one world technology shock, as seen from the results in Section 2 of the Appendix, particularly Table A.2.

As discussed in Section 2, the SVECM is given by (2) in which $\Pi = \alpha\beta'$, where β represents the cointegrating relationships and α the short-term adjustments. We specify β to include both the three cointegrating relationships among the $I(1)$ variables and pseudo-cointegrating terms for the six $I(0)$ variables, where the latter correct for the levels effect that would be lost if using a standard VECM. Then α incorporates both the error-correction coefficients for $I(1)$ variables and "adjustment" coefficients to pseudo-cointegration for the $I(0)$ variables. Section 1 of the Appendix provides further details on the specification of α and β in our SVECM.

3.2 Short-Run Restrictions and Dynamics

We turn now to the detailed specification employed for modelling the short-run interactions between the US, the Euro area and Australia. For each economy, the framework consists of equations for output (together with GNE for Australia) and inflation, both of which allow international influences, together with a monetary policy reaction function, with the model closed by a real exchange rate equation. The detailed specification of the coefficient matrices B_ℓ (for $\ell = 0, 1, 2$) is provided in Section 1 of the Appendix.

Our SVECM with two lags, based on a VAR(3), employs conventional causal ordering assumptions across variable blocks. Taken together with cross-country assumptions, these result in the ordering shown in (5), and hence the contemporaneous coefficient matrix B_0 is lower block triangular. Other structural restrictions are imposed on our system in line with contemporary macroeconomic modelling practice. In all three economies, monetary policy is assumed to be domestically focussed, both contemporaneously and in the lags, reflecting the Taylor rule. With the separation of output and domestic demand in the case of Australia, GNE replaces output in the Taylor rule, in line with Dungey and Pagan (2000, 2009). Nevertheless, the monetary authority is assumed in each case to consider only the course of domestic inflation, output or demand, and the (lagged) interest rate. As in Dungey and Osborn (2013), the domestic output (or GNE) gap is proxied by using output (GNE) growth together with any ecm term that includes the relevant output variable.

Consistent with an international IS curve, foreign output variables are included in each output equation, although with the exogeneity assumption, Australian output does not enter the equations for the US and Euro area. Following Dungey and Pagan (2000), foreign output influences enter via GDP in Australia, rather than through domestic expenditure.

In the domestic sector, we restrict coefficients to ensure that real, rather than nominal, interest rates affect output. For Australia, in addition, the nominal and real interest rate enter the GNE and output equations (respectively) only after two quarters, in order to allow monetary policy to affect output only after a delay. The real exchange rate affects both of these Australian variables, but does not enter the output equations for the large open economies[5].

In line with the empirical findings of Milani (2010) for G7 countries, foreign output does not directly enter into inflation determination for the two large international economies. However, as a small open economy foreign influences are permitted to directly enter the inflation specification for Australia. As in Dungey and Pagan (2009), inflation in Australia is influenced by the GNE (rather than the output) 'gap'. Lagged foreign inflation rates are included to capture international spillovers, with real exchange rates included to account for incomplete pass-through. Finally, the US/Euro area real exchange rate responds to developments in output, inflation and interest rates in both large economies, while the Australian exchange rate responds to all variables in the model except the bilateral US/Euro area exchange rate.

In addition to these endogenous variables, the specification includes commodity price inflation as an exogenous variable in all Australian equations except the monetary policy rule. Two zero/one dummy variables are also incorporated for Australia. The first picks up the introduction of the GST in September 2000 in the Phillips curve and monetary policy rule, while the second identifies the pre-formal inflation targeting period in Australia (1984 quarter 1 - 1999 quarter 4) in the monetary policy rule.

4 Results

The interactions between the US and Euro area themselves in this specification are the same as those in Dungey and Osborn (2013), and due to the small open economy nature of the model, domestic responses to domestic shocks are the same as those in Dungey and Pagan (2009), subject only to a slight change in the sample period. The sizes of the shocks are measured by one-standard deviation of the orthogonal errors. In all three economies there is no evidence of domestic price puzzle or exchange rate puzzles, and the correlations between the residuals of the system are given in Table A3 in the Appendix. Here, our focus is rather on the impact of shocks originating in the US and the Euro area on the Australian economy,

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[5] Dungey and Osborn (2013) note that incusion of the real exchange rate in the output equations for their US/Euro Area model leads to economically implausible results.

and how the interactions between these two major international economies affects these transmissions. Figures A2 to A6 in the Appendix present the full set of impulse responses for the domestic variables with 68% boostrapped confidence bands from 5000 replications.

4.1 Impulse responses: International output shocks

The left hand panel of Figures 1(a)-(d) presents the impact of the US output shock on each of US, Euro area and Australian variables. Output shocks originating in the US have a permanent effect on both US and Australian output, with the effect on Australia being a rise of about half the size of the permanent effect on the US and the impact on European output is half that again (Figure 1(a)).

In contrast, the initial shock to Euro area output results in a permanently lower final Australian output, see Figure 1(e). This is because the shock to Euro area output provokes an aggressive response from the European monetary authorities to raise interest rates in anticipation of future inflation (Figure 1(g)) and subsequent appreciation of the Euro, which results in lower US demand and hence lower US output, as documented in Dungey and Osborn (2013). The consequent lower US output, shown in Figure 1(e), leads to lower Australian output. Thus, despite a positive initial European output shock, the interactions between the two major economies result in a reduction in Australian output.

Consistent with the different output effects of the European and US sourced output shocks, the inflationary consequences are also quite different. A US output shock (see Figures 1(b) to 1(d)) generates inflationary effects in the US and Australia (and interest rates rise). Since the initial rise in US interest rate is greater than the rise in Euro area and Australian interest rates, both the Euro and Australian dollar depreciates. In contrast, since the Euro area output shock results in lower Australian output, there is consequently decreased Australian inflationary pressure and lower interest rates (see Figures 1(e) to 1(h)).

4.2 Impulse responses: International inflation shocks

In response to a US inflation shock, inflation in both the US and Euro area rise, see Figure 2(b). A portion of these strong inflationary effects are passed through to Australia. With both the US and Euro area inflation higher, the Australian dollar (TWI) appreciates, as shown in Figure 2(d), which adversely affects exports in Australia. Thus there is a decline in Australian output. The inflationary pressure results in a rise in domestic interest rates (see Figure 2(c)) and it is not until there is a change in the relative real interest rates of the international and domestic economies that we see the Australian dollar depreciate and restore competitiveness.

The European central bank raises interest rates in response to higher inflation faster, but ultimately less strongly than in the US case (see also Dungey and Osborn, 2013). However, while little of the US shock is transmitted to Australian inflation, in the case of the Euro a substantial portion is transmitted. In this case the Australian dollar depreciates, which reinforces the inflationary outcome for Australia, interest rates rise which results in lower output and domestic activity with a slight delay, see Figures 2(e) -(h).

4.3 Impulse responses: International interest rate shocks

When the US tightens monetary policy, modelled via an unanticipated rise in US interest rates, inflation is contained in the US and Australia - see Figures 3(a)-(d). The Australian output response (Figure 3a) is weak and insignificant. The lower international inflation results in reduced Australian inflation; see Figure 3(b). Consequently, Australian interest rates are lowered by the central bank (see Figure 3(c)), which stimulates GNE to substitute domestic consumption for the lower foreign demand. This analysis provides empirical evidence consistent with the view promoted by the Reserve Bank of Australia that domestic monetary policy responds to domestic economic conditions, and does not simply follow US policy initiatives.

When the Euro area tightens monetary policy, this results in a small reduction in European output and European inflation and also a depreciation of the US dollar relative to the Euro (see Figures 3(e)-(h)). This stimulates US inflation, which flows through to Australian inflation, and lower Australian output. Since the rise in Australian interest rates is minimal, this leads to a depreciation of the Australian dollar.

An interesting development from this analysis is the recognition that when Australian exports are affected by an exchange rate movement then the Australian output and GNE impulse responses have different signs - that is we observe a substitution effect from foreign consumers to domestic consumers by the Australian producers. This reflects the importance of the sources of shocks. However, when source shocks are from international inflation then the resulting higher interest rates result in output and GNE impulses in the same direction, as the central banks act to suppress inflationary pressures in the economy.

4.4 Historical Decomposition

A useful reorganisation of an estimated VAR is the historical decomposition, which exposes the contribution of shocks to the observed outcome at each point in time. Figures 4 and

5 present the historical decomposition of Australian output, inflation, interest rates and exchange rate over the sample.

Figure 4(a) shows the importance of domestic demand (GNE) and US output shocks to variation in Australian output. Euro area output shocks play a lesser role. The period from 1996 is characterised by the strong positive contribution of US sourced shocks to the observed outcome, whilst at the same time domestic demand is providing a smaller negative contribution. This reflects the strong role of exports in the economy during this period. Inflation shocks from any source, make little contribution to output variation over this period (Figure 4b), but Figure 4(c) shows the contribution of Australian monetary policy, via interest rates, during the early 1990s recession was to improve Australian output, and consistent with earlier analysis, there is some evidence that interest rate settings were responsible for instigating that crisis, with interest rates acting to reduce output. The analysis here provides evidence that aggregate demand shocks are dominant in explaining variation in Australian output, but that the sources of those shocks has fluctuated considerably over the sample, with domestic shocks sometimes dominant and positive, but at other times acting as a damper on dominant positive foreign sourced shocks.

The contributions of differently sourced inflation shocks to the variation in Australian inflation are shown in Figures 4(d)-(f). It is clear that in the early to mid 90s, Euro output had a strong negative contribution while at other times both domestically and internationally sourced inflation shocks are the major driver. US interest rate shocks have a discernible, but lesser impact.

The variation in the Australian interest rates over the sample period is primarily explained by three factors: own shocks and shocks from inflation and GNE as shown in Figures 5(a)-(c). That is, corresponding to a monetary policy rule, interest rates vary in response to actual and expected future domestic inflation. The inflation effects are not entirely domestically driven, it is clear that at various times the transmission of inflationary shocks from foreign sources is anticipated in the domestic policy response. In the late 1990s Australia gains a significant negative impetus for inflationary pressures from European inflation (Figure 5b), which aligns well as a dividend from the announced move to the Euro area monetary union and German reunification - this boost to lower inflationary conditions lasts until the mid-2000s. At the same time the accomodatory monetary policy in the US for the decade following the early 1990s recession is also evident in its effects on higher Australian interest rates.

When it comes to the Australian dollar TWI exchange rate, variation in Australian domestic demand (GNE) has contributed the largest shocks; see Figure 5(d)-(f). Thus the domestic economy drives a substantial component of the signalling for the value of the currency. Interestingly, the US shocks tend to be in offsetting direction, simply reflecting the effect of shocks from the world's major financial market.

Figures 6(a) and (b) breakdown the components of the shocks affecting the Australian dollar TWI variation due to shocks originating from each country, and shocks originating from each of the different variables types. Figure 6(a) indicates that shocks originating from Australia dominate; output shocks make up the majority of these effects. Figure 6(b) indicates the dominance of the contribution of output and it is clear that inflation and interest rate effects are secondary. This is consistent with Voss and Willard (2009), and suggests that Euro area developments are relatively unimportant in driving developments in the Australian dollar TWI.

The analysis of our three economy system, where two major economies interact and influence the small open economy provides us with some useful insights as to the nature of international effects on Australia. Shocks originating in a major economy have a smaller impact on the other interdependent large economy than they do on Australia. That is, shocks originating in the US often have a larger impact on Australian output and inflation than the do on Europe. Similarly, European originated shocks have a larger impact on Australian output and inflation than they do on the US. The separation of the region of origin of the shocks provides some useful insights into the propogation of those effects into Australia. For example, a US output shock stimulates US output and hence Australian output, and inflation increases in both those countries. Consequently, Australian interest rates rise. In contrast, a European output shock does not lead to higher Australian inflation - higher European output leads to an appreciation of the Euro and consequently an insignificant contraction in the US economy. This is transmitted to Australia, and results in lower inflation and hence a fall in interest rates. Thus, we illustrate the potential complexity of the transmission mechanisms for shocks sourced in different regions. Overall, the responses in the Australian economy are aligned with those of the US. The historical decompositions of Australian output support the strong role of the US, but the evolution of inflation has reaped a substantial benefit during the 1990s from German reunification and the move towards monetary union.

5 Conclusion

To our knowledge, this paper provides the first analysis of the effects of international shocks on the Australian economy that separately identifies the effects of shocks from the US and the Euro area, allowing these to lead to distinct response patterns in Australian variables. Most previous studies, including Dungey and Pagan (2000, 2009), Buncic and Melecky (2008), Voss and Willard (2009) and Leu (2011) take the US to represent foreign influences in a small open economy framework, but our results show that the Euro area is also important. To be specific, although we confirm the important role of US growth for Australia while there are effectively no spillovers from Euro area output growth to Australian GDP, inflation and interest rate variables generally show Euro area shocks to be as important as those of the US. Hence effects differ, depending not only on the domestic variable being considered but also on the foreign economy in which the shock is sourced.

The econometric framework we employ uses exogeneity restrictions for the large international economies in relation to Australia. By also employing realistic economic restrictions on individual equations, we conserve degrees of freedom in a structural VAR context. An important advantage of our framework is that interactions are also allowed between the US and Euro area, which therefore recognises the complexities of the international economy.

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Figure 1. Impulse Responses of All Variables to US and EA Output Shocks

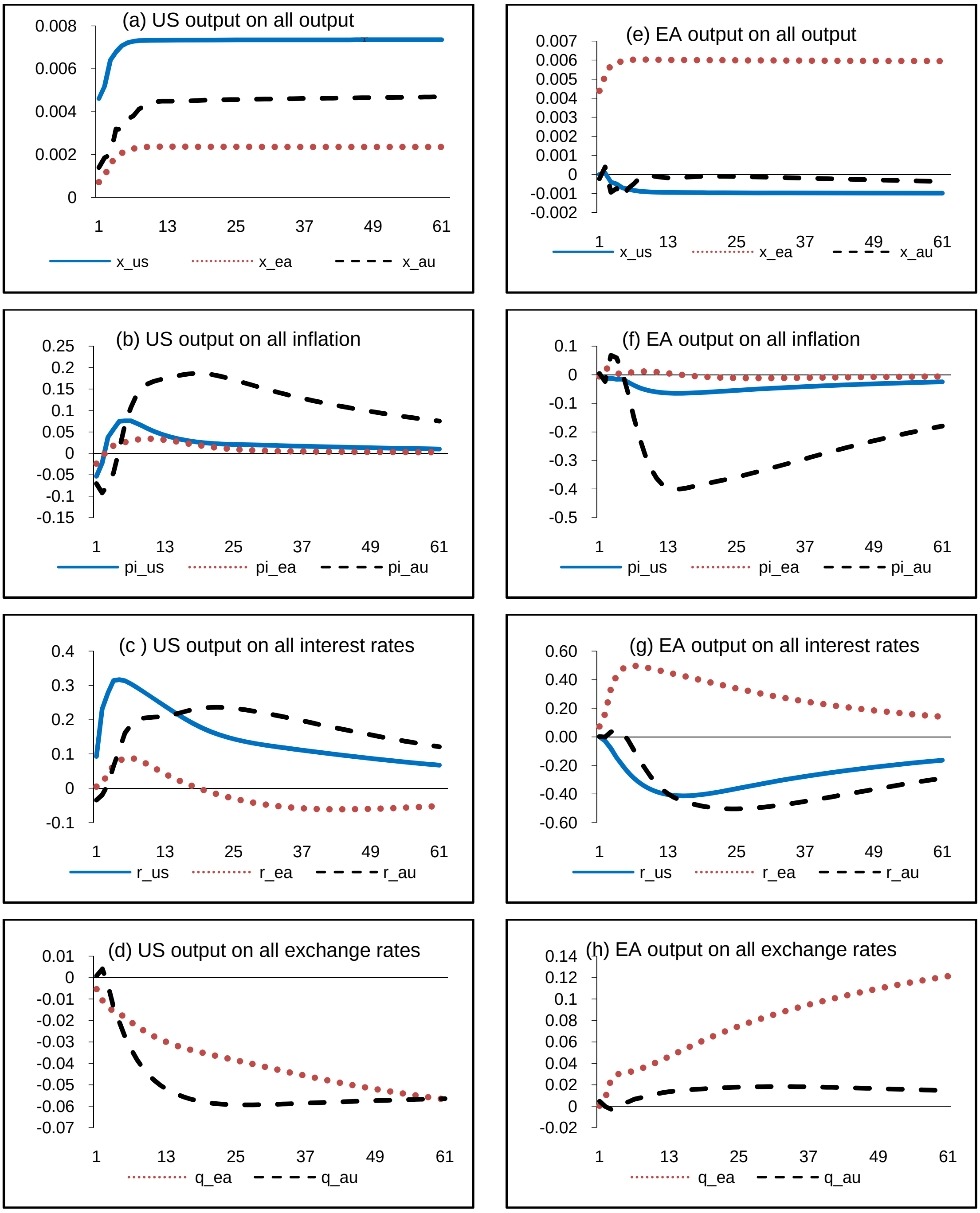


Figure 2. Impulse Responses of All Variables to US and EA Inflation Shocks

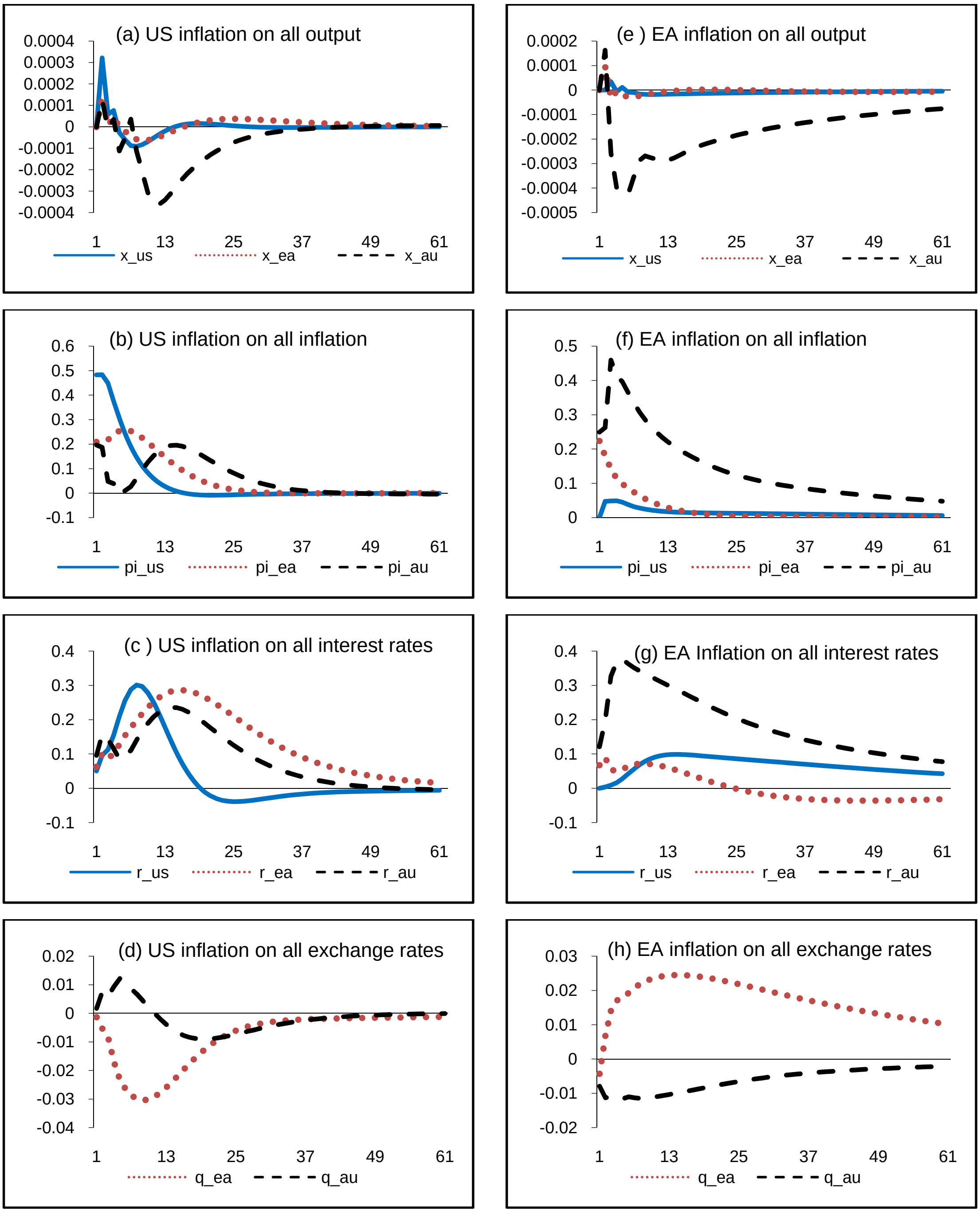


Figure 3. Impulse Responses of All Variables to US and EA Interest Rate Shocks

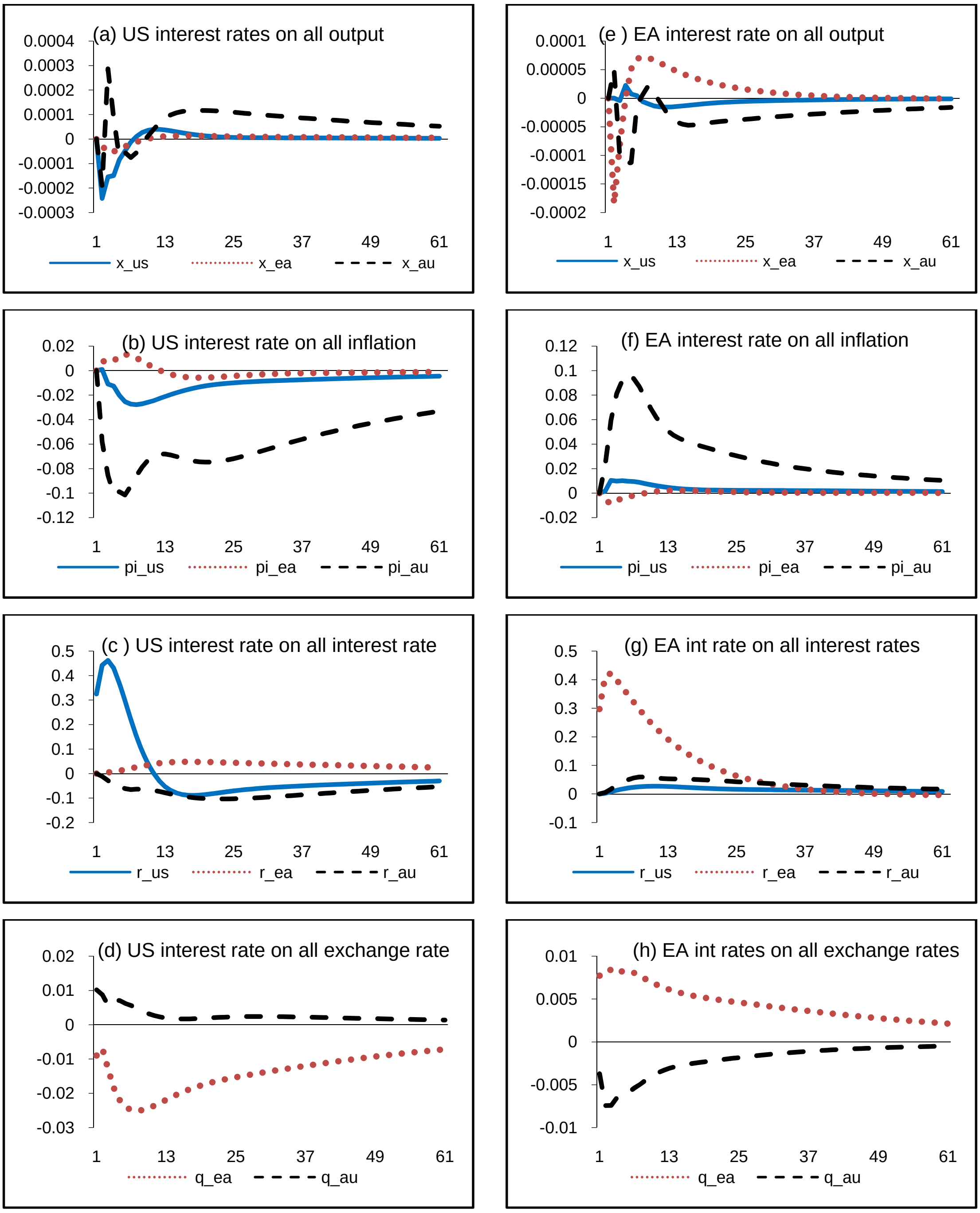


Figure 4. Historical Decomposition of Australian Output and Inflation to Various Shocks

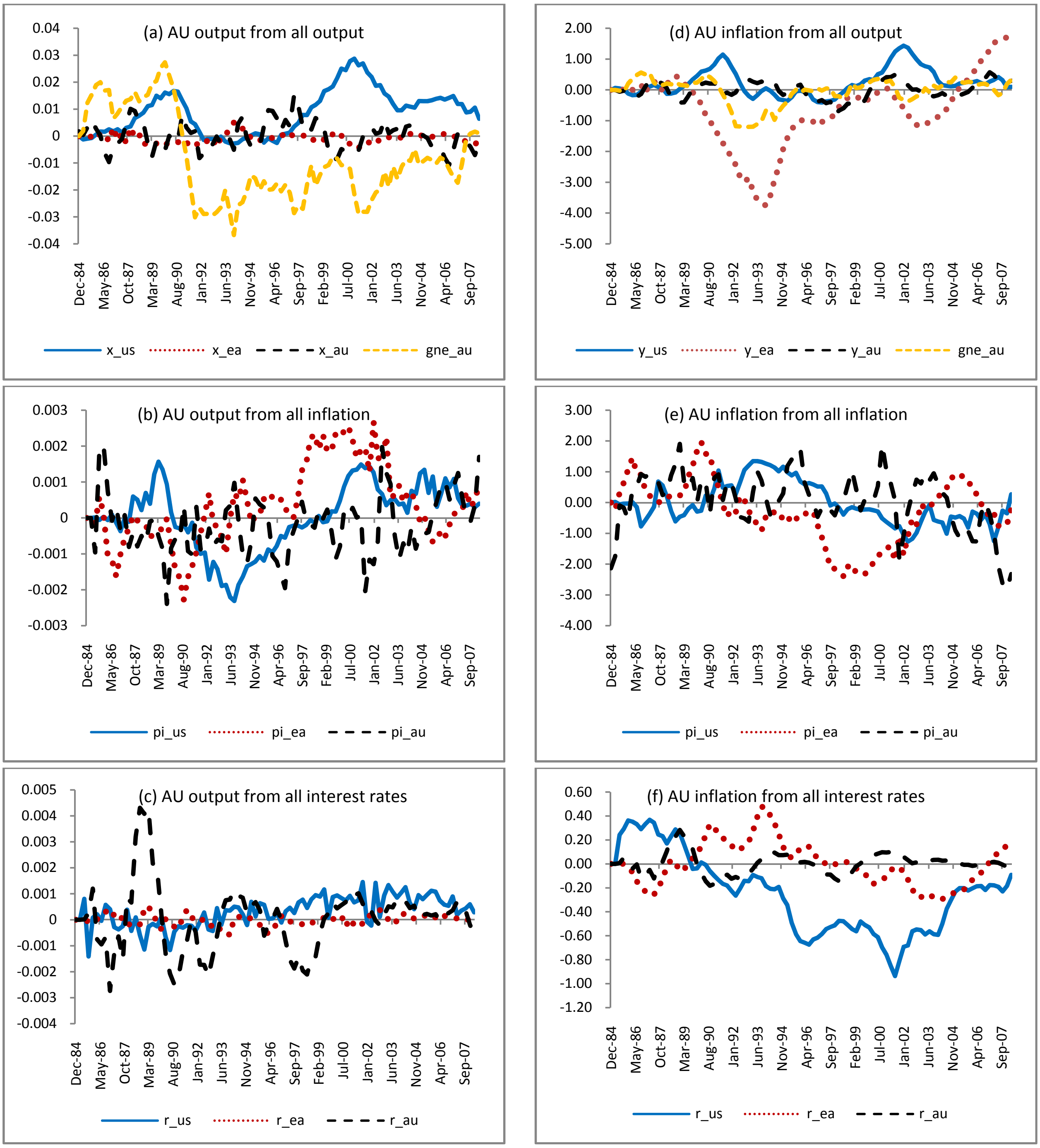


Figure 5. Historical Decomposition of Australian interest rates and exchange rates to Various Shocks

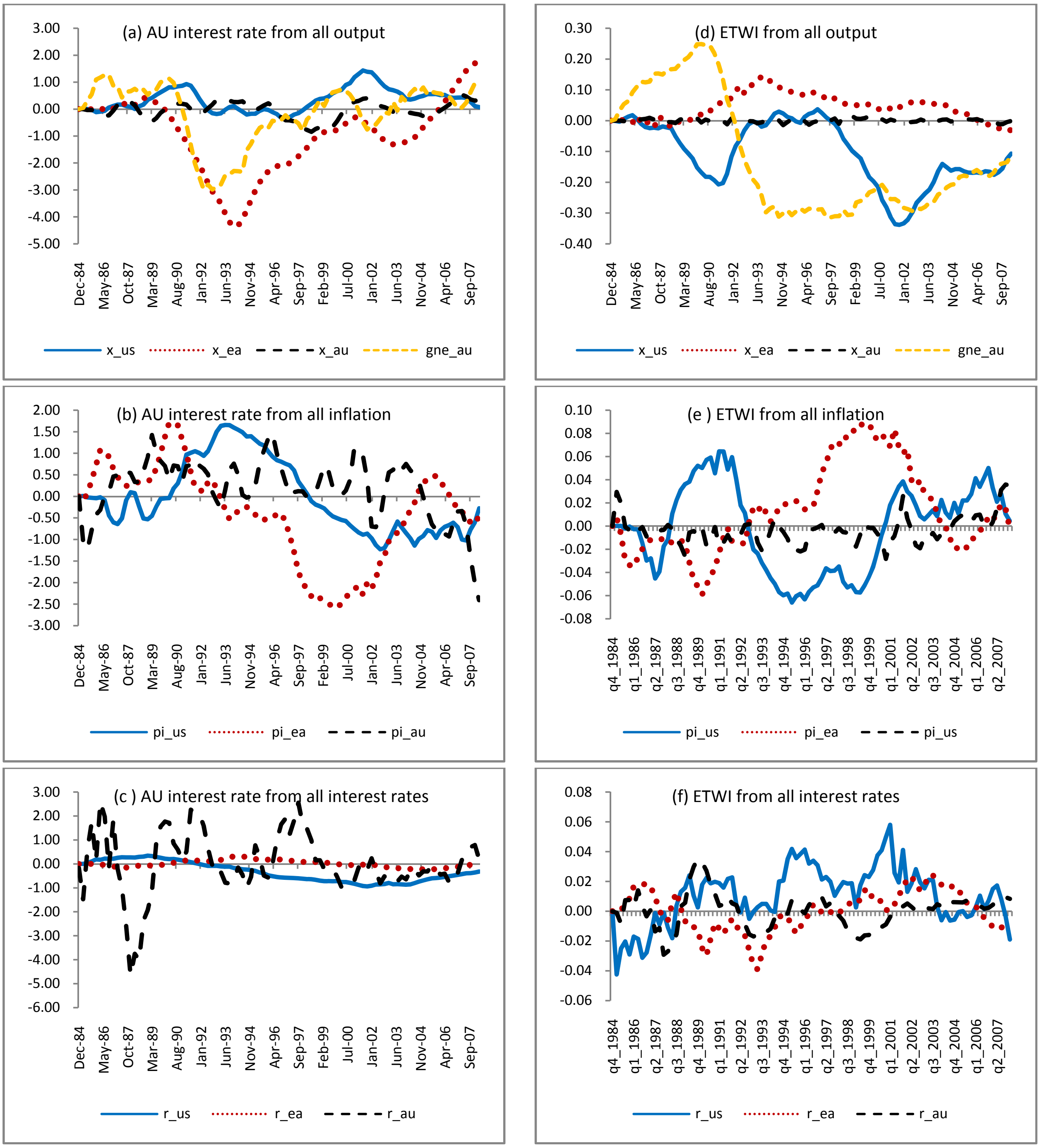
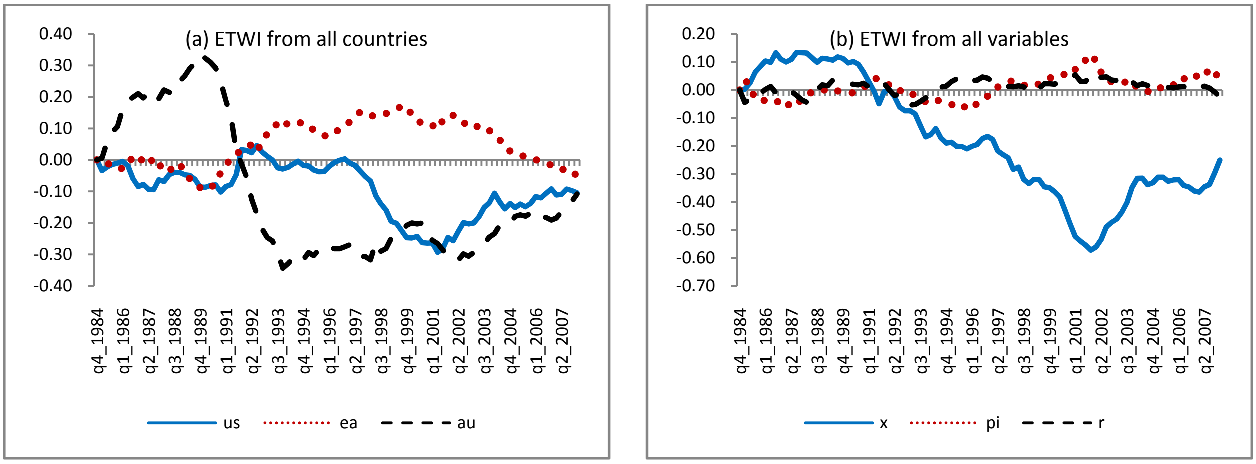


Figure 6. Historical Decomposition of Australian Exchange Rates by Countries and by Variables



Appendix

Section 1: Detailed Specification of SVECM Matrices

The form of the three cointegration and six pseudo-cointegration relationships are reflected in the rows of β':

$$\beta' = \left[\begin{array}{cccc c c c cc}
\beta_{1,1} & 1 & 0 & 0 & \vdots & & \vdots & \beta_{1,11} & 0 \\
\beta_{2,1} & 0 & 0 & 1 & \vdots & 0_{3\times 6} & \vdots & 0 & \beta_{2,12} \\
0 & 0 & 1 & \beta_{3,4} & \vdots & & \vdots & 0 & \beta_{3,12} \\
\cdots & \cdots & \cdots & \cdots & & \cdots & & \cdots & \cdots \\
 & & 0_{6\times 4} & & \vdots & I_{6\times 6} & \vdots & & 0_{6\times 2}
\end{array}\right]$$

in which the first column partition relates to variables of the output block $(x^{us}, x^{ea}, gne^{au}, x^{au})$, the second to the inflation and interest rate blocks and the final column partition to the exchange rate block (q^{ea}, q^{au}). In an obvious notation, the dimensions of zero and identity matrix partitions are indicated when these contain more than one element.

For the adjustment coefficients, the first three rows of α consist of zeros, as the corresponding variables (x^{us}, x^{ea} and gne^{au}) are specified as the sources of the permanent shocks. The final row of the output block (for x^{au}) has non-zero adjustment coefficients to the three cointegrating relationships and all other elements zero. Rows 5 to 7 of α relate to the inflation block $(\pi^{us}, \pi^{ea}, \pi^{au})$ and have the form

$$\left[\begin{array}{ccc c ccc c c}
\alpha_{5,1} & 0 & 0 & \vdots & \alpha_{5,4} & \alpha_{5,5} & 0 & \vdots & \\
\alpha_{6,2} & 0 & 0 & \vdots & \alpha_{6,4} & \alpha_{6,5} & 0 & \vdots & 0_{3\times 3} \\
\alpha_{7,3} & \alpha_{7,2} & \alpha_{7,2} & \vdots & \alpha_{7,4} & \alpha_{7,5} & \alpha_{7,6} & \vdots &
\end{array}\right]$$

in which the first column partition contains the adjustment coefficients to the cointegrating relationships, while the second and third column partitions contain the coefficients of the pseudo-cointegrating relationships for inflation and interest rates, respectively. Therefore the coefficients in the second column partition act to convert equations in differences to ones in the levels of inflation. As in Dungey and Osborn (2013), the output gap is proxied by including output growth and the corresponding error-correction term from the cointegrating relationship; this leads to the inclusion of the US/Euro area output error-correction term in the inflation equation for each country, together with the error-correction terms from both cointegrating relationships relating to Australia in the Australian inflation equation.

The adjustment coefficients in the equations for the variables of the interest rate block (r^{us}, r^{ea}, r^{au}) reflect the assumption that monetary policy is domestically focussed. Using the same column partitions for α as above, the rows for the interest rate block are

$$\left[\begin{array}{ccccccccccc} \alpha_{8,1} & 0 & 0 & \vdots & \alpha_{8,4} & 0 & 0 & \vdots & \alpha_{8,7} & 0 & 0 \\ \alpha_{9,1} & 0 & 0 & \vdots & 0 & \alpha_{9,5} & 0 & \vdots & 0 & \alpha_{8,8} & 0 \\ 0 & \alpha_{10,2} & \alpha_{10,3} & \vdots & 0 & 0 & \alpha_{10,6} & \vdots & 0 & 0 & \alpha_{10,9} \end{array}\right].$$

The adjustment coefficients $\alpha_{8,1}$, $\alpha_{9,1}$, $\alpha_{10,2}$ and $\alpha_{10,3}$ are once again included in order to capture relevant output gap effects, with all other coefficients acting to convert inflation and interest rates to levels form. Finally, the adjustment matrix coefficients in the exchange rate equations, namely

$$\left[\begin{array}{ccccccccccc} \alpha_{11,1} & 0 & 0 & \vdots & \alpha_{11,4} & \alpha_{11,5} & 0 & \vdots & \alpha_{11,7} & \alpha_{11,8} & 0 \\ \alpha_{12,1} & \alpha_{12,2} & \alpha_{12,3} & \vdots & \alpha_{12,4} & \alpha_{12,5} & \alpha_{12,6} & \vdots & \alpha_{12,7} & \alpha_{12,8} & \alpha_{12,9} \end{array}\right],$$

allow the exchange rates to react to all relevant variables of the model. However, the exogeneity assumption for Australia in relation to the US and Euro area restricts coefficients relating to Australia to be zero in the euro/US dollar exchange rate equation.

For the short-run dynamics, the form of coefficient matrices B_ℓ of equation (2) for $l = 0$, 1, 2 are again discussed in terms of the equations for the output, inflation, interest rate and exchange rate blocks. The equations of the output block $(x^{us}, x^{ea}, gne^{au}, x^{au})$ have coefficients

$$\left[\begin{array}{cccccccccccccccc} b_{1,1}^{(l)} & b_{1,2}^{(l)} & 0 & 0 & \vdots & -b_{1,8}^{(l)} & 0 & 0 & \vdots & b_{1,8}^{(l)} & 0 & 0 & \vdots & 0 & 0 \\ b_{2,1}^{(l)} & b_{2,2}^{(l)} & 0 & 0 & \vdots & 0 & -b_{2,9}^{(l)} & 0 & \vdots & 0 & b_{2,9}^{(l)} & 0 & \vdots & 0 & 0 \\ 0 & 0 & b_{3,3}^{(l)} & 0 & \vdots & 0 & 0 & b_{3,7}^{(l)} & \vdots & 0 & 0 & b_{3,10}^{(l^*)} & \vdots & 0 & b_{3,12}^{(l)} \\ b_{4,1}^{(l)} & b_{4,2}^{(l)} & b_{4,3}^{(l)} & b_{4,4}^{(l)} & \vdots & 0 & 0 & -b_{4,10}^{(l^*)} & \vdots & 0 & 0 & b_{4,10}^{(l^*)} & \vdots & 0 & b_{4,12}^{(l)} \end{array}\right]$$

where the column partitions of B_ℓ relate to the output, inflation, interest rate and exchange rate blocks, respectively. Note that the coefficients indicated as $b_{ij}^{(l^*)}$ for $i = 3, 4$ are nonzero for $l = 2$ only; as noted in the text, the latter restrictions allow for monetary policy to effect GNE and GDP in Australia only after a lag of two quarters. For all three countries, the real interest rate restrictions $b_{1,5}^{(l)} = -b_{1,8}^{(l)}$, $b_{2,6}^{(l)} = -b_{2,9}^{(l)}$, $b_{4,7}^{(l)} = -b_{4,10}^{(l)}$ are imposed in the GDP equations. In addition, in this and all row blocks contemporaneous causality restrictions are imposed such that $b_{i,j}^{(0)} = 0$ for $j > i$, while the diagonal elements $b_{i,i}^{(0)} = 1$ (in both cases for $i = 1, 2, ..., 12$).

Turning to the inflation equations, the relevant elements of B_ℓ have the form

$$\left[\begin{array}{cccccccccccc} b_{5,1}^{(l)} & 0 & 0 & 0 & \vdots & b_{5,5}^{(l)} & b_{5,6}^{(l)} & 0 & \vdots & & \vdots & b_{5,11}^{(l)} & 0 \\ 0 & b_{6,2}^{(l)} & 0 & 0 & \vdots & b_{6,5}^{(l)} & b_{6,6}^{(l)} & 0 & \vdots & 0_{3\times 3} & \vdots & b_{6,11}^{(l)} & 0 \\ b_{7,1}^{(l)} & b_{7,2}^{(l)} & b_{7,3}^{(l)} & 0 & \vdots & b_{7,5}^{(l)} & b_{7,6}^{(l)} & b_{7,7}^{(l)} & \vdots & & \vdots & 0 & b_{7,12}^{(l)} \end{array}\right]$$

as discussed in the main text. As also discussed in the text, the domestically-focussed interest rate equations imply that rows 8 to 10 are

$$\begin{bmatrix} b_{8,1}^{(l)} & 0 & 0 & 0 & \vdots & b_{8,5}^{(l)} & 0 & 0 & \vdots & b_{8,8}^{(l)} & 0 & 0 & \vdots & \\ 0 & b_{9,2}^{(l)} & 0 & 0 & \vdots & 0 & b_{9,6}^{(l)} & 0 & \vdots & 0 & b_{9,9}^{(l)} & 0 & \vdots & 0_{3\times 2} \\ 0 & 0 & b_{10,3}^{(l)} & 0 & \vdots & 0 & 0 & b_{10,7}^{(l)} & \vdots & 0 & 0 & b_{10,10}^{(l)} & \vdots & \end{bmatrix}$$

while the exchange rate equations have coefficients given by

$$\begin{bmatrix} b_{11,1}^{(l)} & b_{11,2}^{(l)} & 0 & 0 & \vdots & b_{11,5}^{(l)} & b_{11,6}^{(l)} & 0 & \vdots & b_{11,8}^{(l)} & b_{11,9}^{(l)} & 0 & \vdots & b_{11,11}^{(l)} & 0 \\ b_{12,1}^{(l)} & b_{12,2}^{(l)} & b_{12,3}^{(l)} & b_{12,4}^{(l)} & \vdots & b_{12,5}^{(l)} & b_{12,6}^{(l)} & b_{12,7}^{(l)} & \vdots & b_{12,8}^{(l)} & b_{12,9}^{(l)} & b_{12,10}^{(l)} & \vdots & 0 & b_{12,12}^{(l)} \end{bmatrix}.$$

Therefore, the US/Euro area exchange rate is affected by all variables relating to those economies, but not Australian variables. Since the real exchange rate series for Australia is a trade-weighted index for the Australian dollar, it is influenced by all variables in the model.

Section 2. Data Issues

Table A.1 Unit Root Test Results

Series	ADF		Phillips-Perron	
x_t^{us}	-2.17	(0.501)	-2.00	(0.593)
x_t^{ea}	-3.03	(0.128)	-1.89	(0.649)
gne_t^{au}	-1.63	(0.773)	-1.47	(0.833)
x_t^{au}	-2.36	(0.397)	-2.09	(0.544)
π_t^{us}	-1.90	(0.326)	-2.88*	(0.050)
π_t^{ea}	-1.95	(0.306)	-3.37*	(0.014)
π_t^{au}	-2.11	(0.240)	-2.12	(0.235)
r_t^{us}	-1.23	(0.658)	-2.15	(0.239)
r_t^{ea}	-1.43	(0.559)	-1.44	(0.558)
r_t^{au}	-1.89	(0.335)	-1.68	(0.436)
q_t^{ea}	-2.69	(0.079)	-1.90	(0.329)
q_t^{au}	-1.48	(0.537)	-1.69	(0.431)

Notes: ADF is the Augmented Dickey-Fuller test, with augmentation selected by AIC with a maximum of 8 lags. The Phillips-Perron test is applied with the Bartlett kernel and automatic Newey-West band-width selection. Values in parentheses are p-values. Tests for x_t^{us}, x_t^{ea}, gne_t^{au} and x_t^{au} allow an intercept and trend; all others allow an intercept only. * indicates the statistic is significant at 5%.

The US data are sourced from Datastream as quarterly GDP, the quarterly average of US CPI inflation, the quarterly average of end-month 3 month t-bill rates. Euro area GDP data are sourced from the AWM database of November 2008. However, the fixed historical (GDP) weights used in AWM are distortionary early in the sample, so we adopt the series calculated with a sliding weight mechanism in Anderson et al (2011) for inflation and interest rates until January 1994. From then Euro area HICP inflation data are used, while the interest rate is represented by the 3 month Euribor rate from the beginning of 1992. The equivalent process is applied to the bilateral exchange rate series prior to January 1999 as in Dungey and Osborn (2013). The series are shown in the Figure A1. Unit root test results for all series are shown in Table A.1.

Table A.2 Johansen Cointegration Tests

	All variables		Excluding q_t^{ea}/q_t^{au}	
Variables and hypotheses	Trace	Max Eigenvalue	Trace	Max Eigenvalue
x_t^{us}, x_t^{ea}, gne_t^{au}, x_t^{au}, q_t^{ea}, q_t^{au}				
H_0: $n = 0$	0.000**	0.000**	0.017**	0.009**
H_0: $n = 1$	0.013**	0.119	0.318	0.231
H_0: $n = 2$	0.074*	0.154	0.723	0.734
H_0: $n = 3$	0.271	0.210	0.402	0.403
R test for over dentifying restrictions on the cointegrating relationships:				
Chi-square(3)	2.083038			
Probability	0.555352			

Notes: All reported results are obtained using EViews employing a VAR(3) (that is, with 2 lagged differences) and unrestricted intercepts, as in Dungey and Osborn (2013). The vaues shown are p-values for the null hypothesis of n cointegrating vectors. * indicates significant at 10% and ** indicates significant at 5%.

Table A.2 provides the cointegration results underlying the three cointegrating relationships discussed in subsection 3.1. In addition to Johansen test results for a VAR containing all six $I(1)$ variables, results are shown for smaller VARs which embed the three distinct cointegrating relationships identified. Following Dungey and Osborn (2013), all results in the table are based on models including two lagged differences (that is, VAR(3) in levels); this is sufficient to take account of autocorrelation in all VAR specifications considered in the table. To investigate whether the variables are driven by a single international permanent technology shock (evidence for which is found by Rabanal *et al.*, 2011), the analysis is undertaken both including and excluding the real exchange rate variables.

The results of Table A.2 support the presence of three cointegrating relationships among the $I(1)$ variables, with inclusion of the real exchange rate series crucial in this finding. In the smaller VAR specifications, the weakest evidence for cointegration relates to the domestic Australian relationship. However, a long-run relationship must exist between GNE and output, with the relatively weak evidence of cointegration presumably reflecting the characteristics of the Australian economy over the sample period.

Table A.3 Residual Correlations of the model

	x_t^{us}	x_t^{ea}	gne_t^{au}	x_t^{au}	π_t^{us}	π_t^{ea}	π_t^{au}	r_t^{us}	r_t^{ea}	r_t^{au}	q_t^{ea}	q_t^{au}
x_t^{us}	1.000											
x_t^{ea}	-0.018	1.000										
gne_t^{au}	0.152	-0.096	1.000									
x_t^{au}	0.015	0.006	-0.003	1.000								
π_t^{us}	-0.018	0.057	-0.171	0.003	1.000							
π_t^{ea}	0.056	0.009	0.086	-0.121	0.018	1.000						
π_t^{au}	0.002	0.003	-0.087	0.087	0.001	-0.005	1.000					
r_t^{us}	0.026	-0.037	-0.122	-0.117	0.002	0.050	0.214	1.000				
r_t^{ea}	0.112	-0.021	0.009	-0.145	0.062	-0.070	0.069	0.111	1.000			
r_t^{au}	-0.014	0.038	-0.052	0.019	-0.061	-0.117	-0.037	-0.058	0.098	1.000		
q_t^{ea}	0.000	0.000	-0.026	0.050	0.000	0.000	-0.159	0.000	0.000	-0.270	1.000	
q_t^{au}	0.000	0.000	0.000	0.000	0.000	-0.008	0.075	0.000	0.000	-0.032	-0.115	1.000

Section 3: Figures

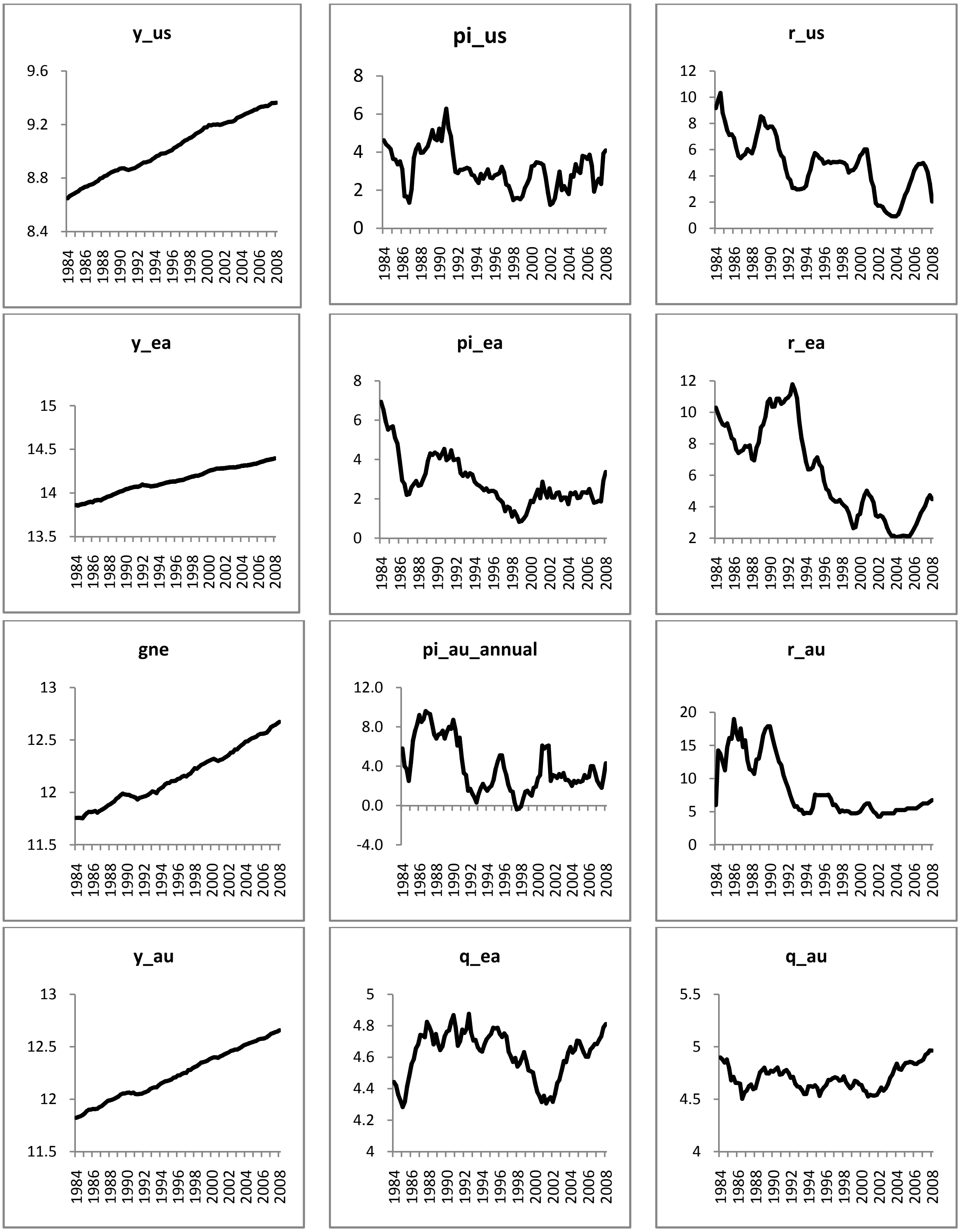
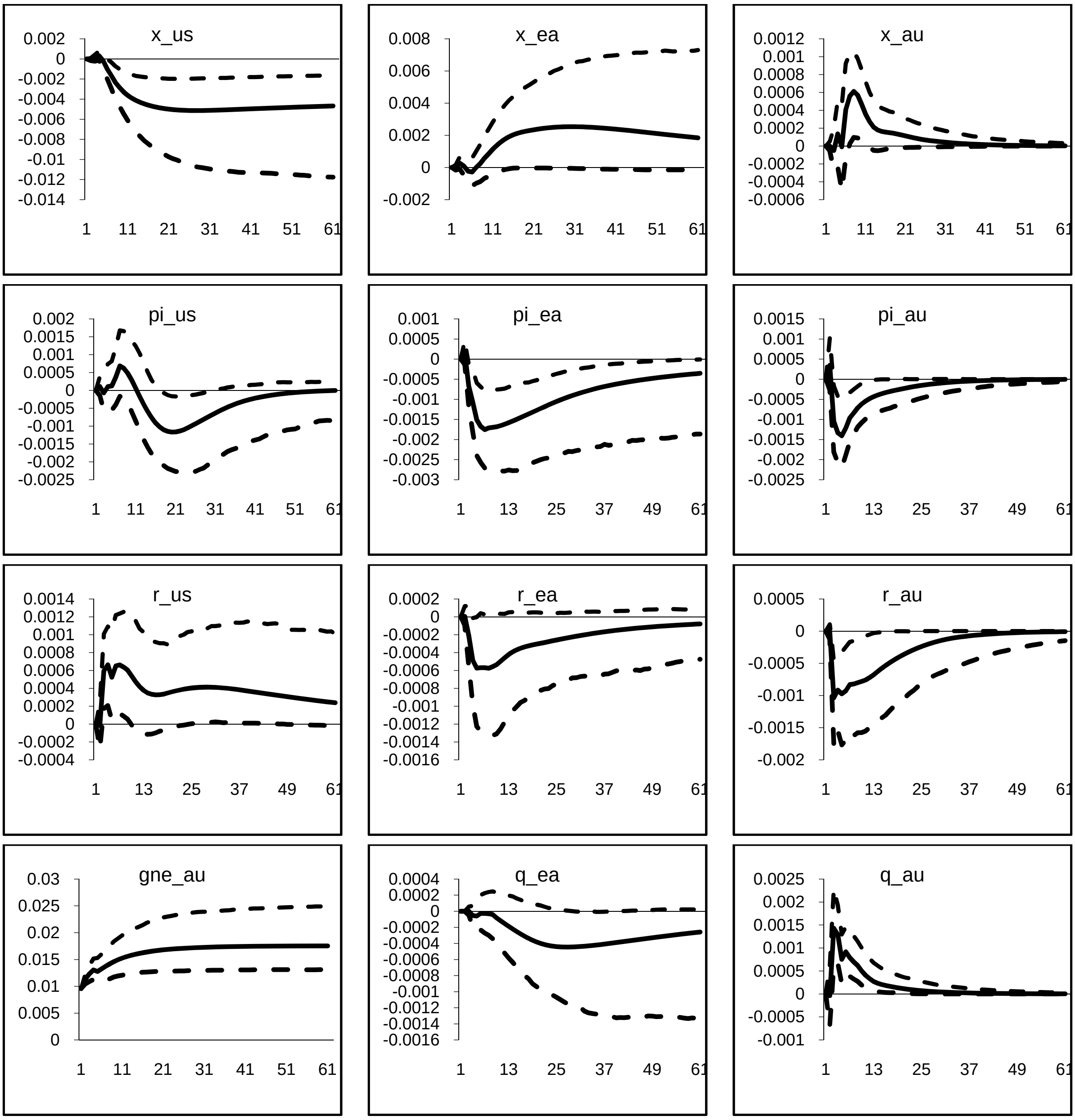


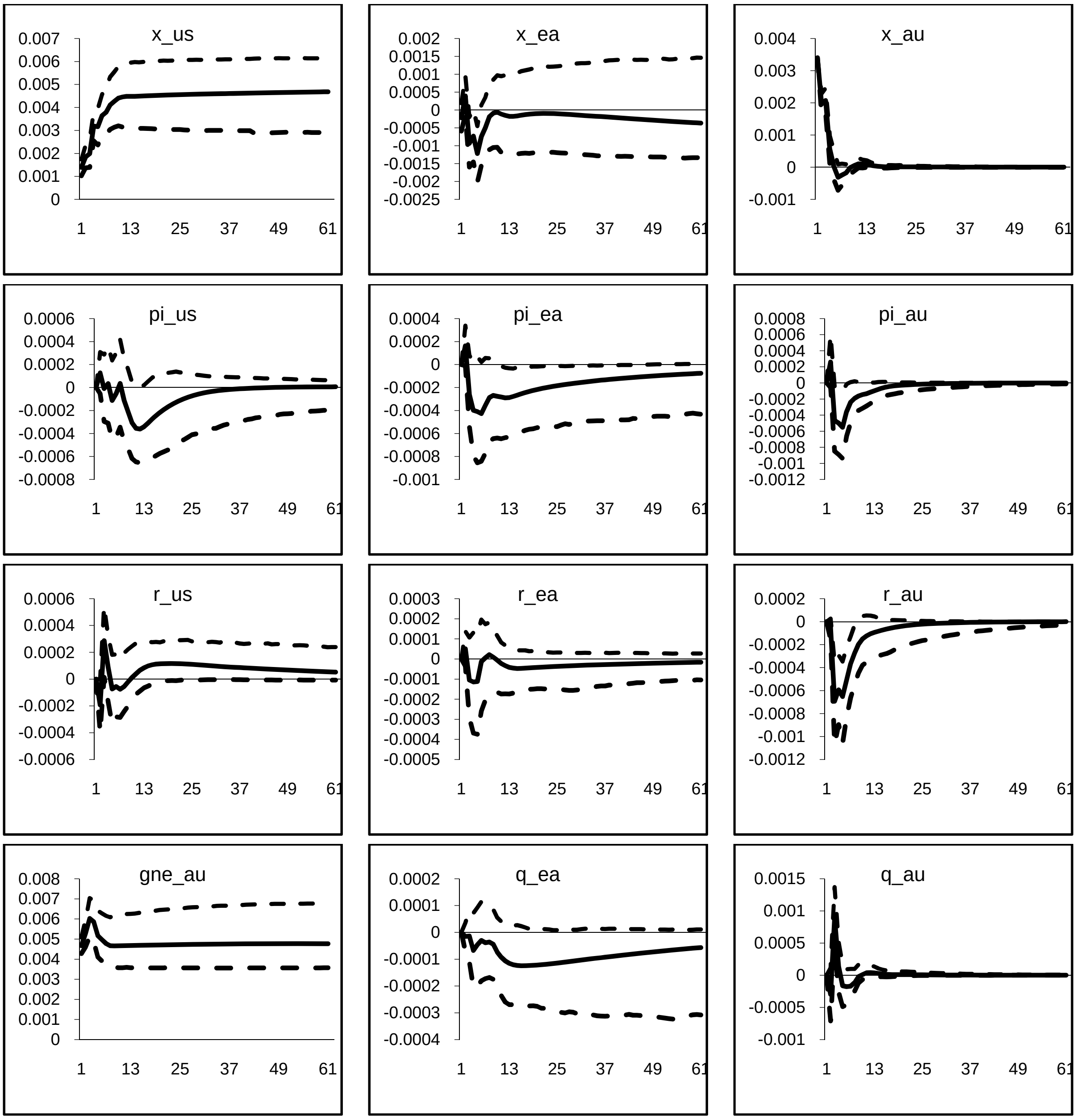
Figure A.1: Data for the US, the Euro Area and Australia

Figure A.2 Impulse Responses of Australian GNE to All Variables



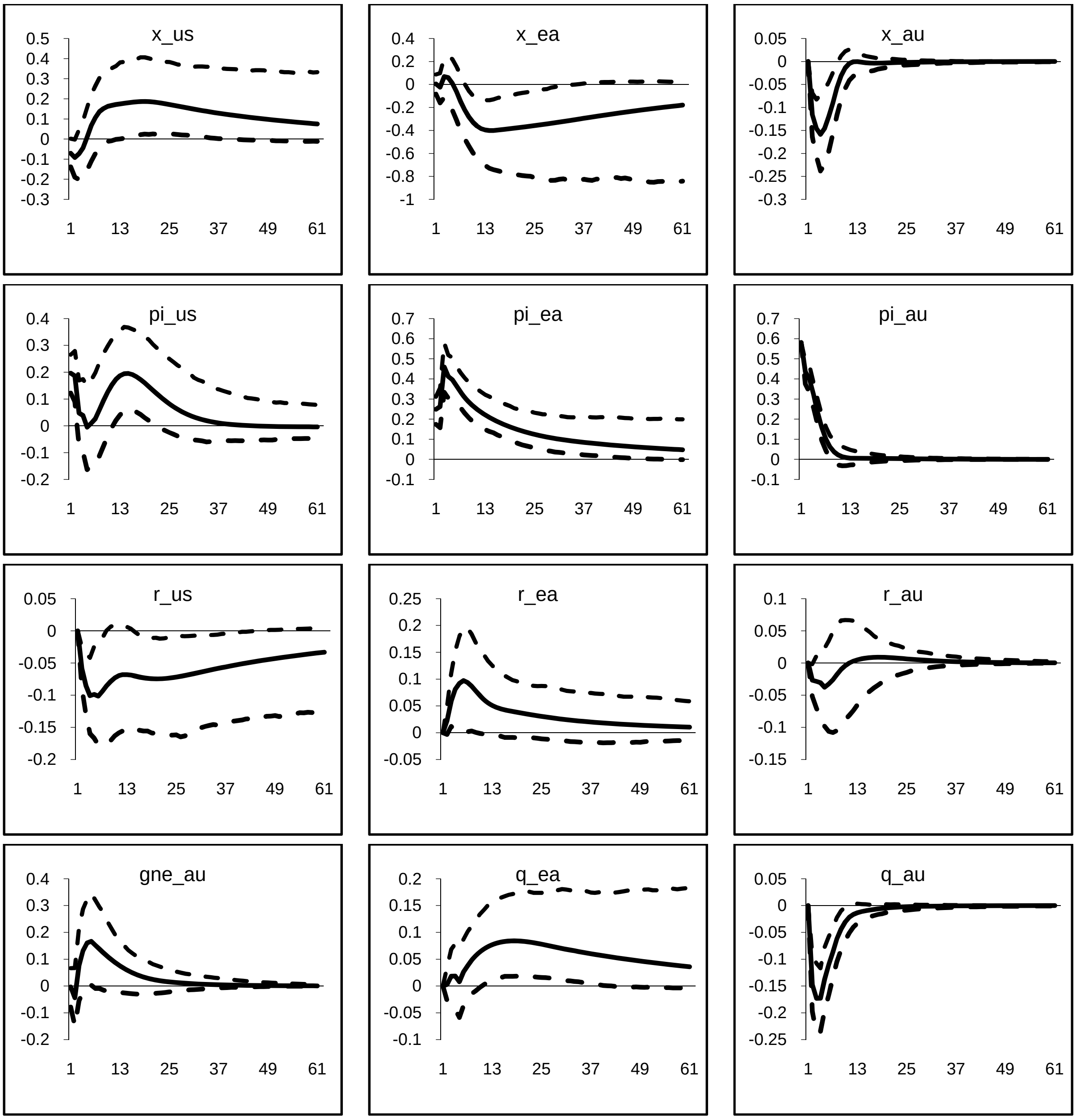
Notes: Impulse responses are shown as unbroken black lines with 68% confidence bands (obtained from 5000 bootstrap replications) shown as dashed lines.

Figure A.3 Impulse Responses of Australian Output to All Variables



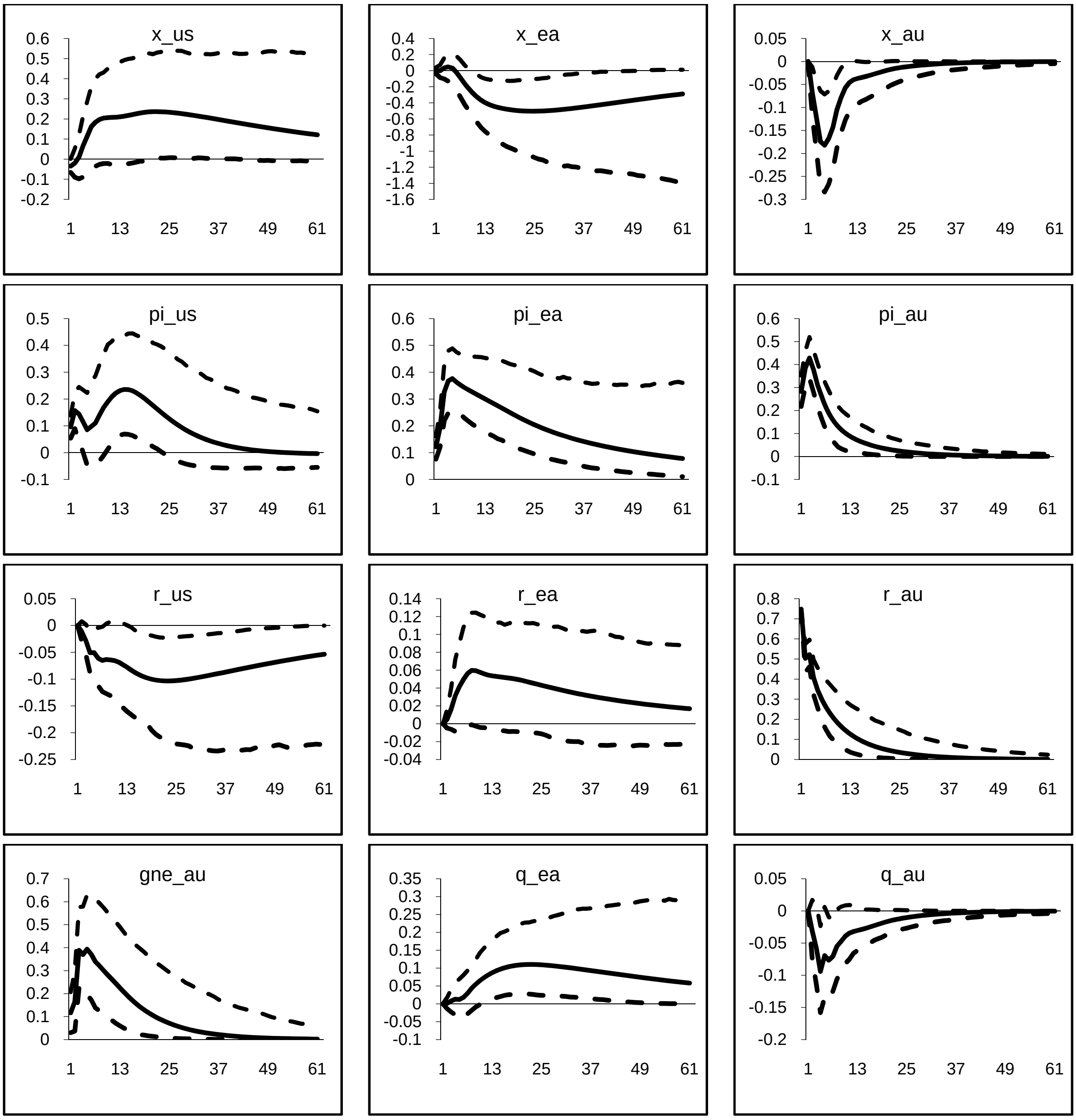
Notes: Impulse responses are shown as unbroken black lines with 68% confidence bands (obtained from 5000 bootstrap replications) shown as dashed lines.

Figure A.4 Impulse Responses of Australian Inflation to All Variables



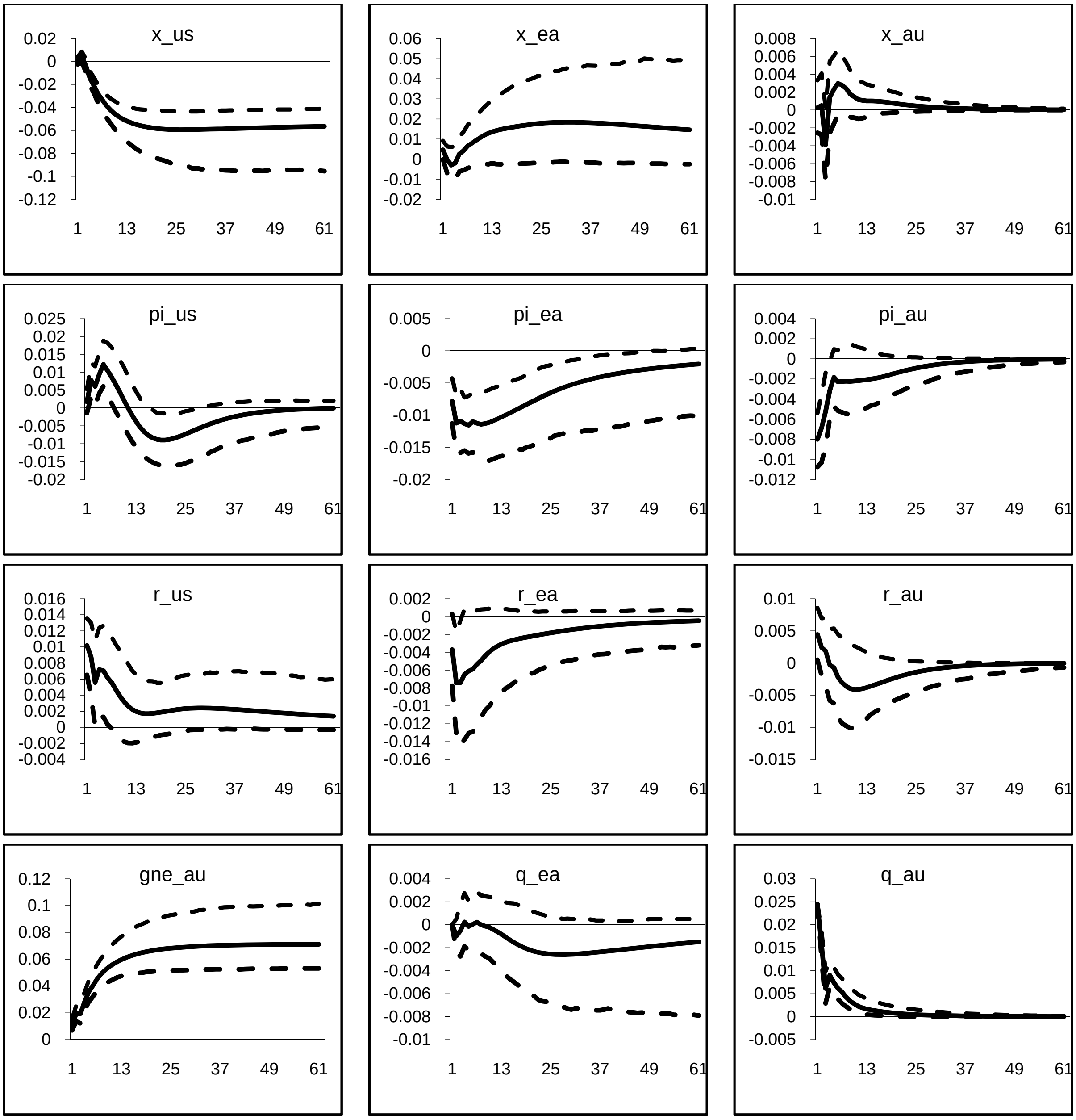
Notes: Impulse responses are shown as unbroken black lines with 68% confidence bands (obtained from 5000 bootstrap replications) shown as dashed lines.

Figure A.5 Impulse Responses of Australian Interest Rates to All Variables



Notes: Impulse responses are shown as unbroken black lines with 68% confidence bands (obtained from 5000 bootstrap replications) shown as dashed lines.

Figure A.6 Impulse Responses of Australian Exchange Rates to All Variables



Notes: Impulse responses are shown as unbroken black lines with 68% confidence bands (obtained from 5000 bootstrap replications) shown as dashed lines.

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