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Abstract

The purpose of this paper is to examine two factors, gold production and export prices, that have been suggested as having aided Australia's escape from the deflation it faced in the early 1890s. In order to examine the factors influencing Australian domestic prices in the second half of the nineteenth century, annual data over the period 1861-1900 are used to estimate a structural vector autoregression. Causality tests in a reduced form vector autoregression suggest that two factors Granger cause the movements in Australian domestic prices, namely export prices and net exports. In contrast, movements in gold production in Australia do not significantly directly cause Australian domestic prices, but have some indirect effect through the interest rate and net exports. Impulse response functions computed from the structural vector autoregression suggest that shocks in export prices lead to a rise in domestic prices, but shocks in gold production do not. Perhaps surprisingly, an export price shock leads to a fall in net exports in the medium term. Changes in capital flows would appear to be an important adjustment channel.

1. Introduction

Over the four years from 1891 to 1895, Australia experienced an average deflation of 4.5% per annum. Over the same period, real gross domestic product fell by an average of 7.1% per annum. Along with the depression in the 1930s, the experience in the early 1890s is rated as one of the two severest macroeconomic depressions that Australia has experienced in the last 150 years (see Fisher and Kent (1999)). Unlike Britain, Australia did not experience general deflation over the period 1870-1890.

The purpose of this paper is to provide some evidence on the factors that aided Australia's escape from the deflation it faced in the early 1890s, and on the mechanisms at work. It has been suggested that two factors that were important in aiding Australia's escape were the discovery of gold in Western Australia in 1893 (see Bassett (1994)), and a recovery in the export prices (and exports). While alluvial gold was discovered in 1887-89 at Southern Cross, the major discoveries at Kalgoorlie did not occur until 1893 (Shann (1988)). In his presidential address to the Australian Economic Association in 1897, Scott (1897), for example, stressed the inflationary nature of these gold discoveries.

In order to examine the factors influencing Australian domestic prices in the second half of the nineteenth century, annual data over the period 1861-1900 are used to first to estimate a standard vector autoregression (VAR). The variables included in the VAR are the export price, net exports, real GDP, a domestic price, gold production, net additions to gold holdings, and a domestic interest rate. Causality tests in this reduced form vector autoregression suggest that two factors Granger cause the movements in Australian domestic prices, namely export prices and net exports. In contrast, movements in gold production in Australia do not significantly directly cause Australian domestic prices, but have some indirect effect through the interest rate and net exports. To determine

how the Australian economy responded in this period to export price shocks, export shocks, and gold production shocks, impulse response functions were computed. To avoid the problems of the dependence of the ordering of variables in computing these impulse response functions, estimation of a structural vector autoregression (SVAR) was attempted. Impulse response functions computed using the results of this structural vector autoregression suggest that shocks in export prices lead to a rise in domestic prices, but shocks in gold production do not. Perhaps surprisingly, export price shocks lead to falls in net exports in the medium term. Changes in capital flows would appear to be an important adjustment channel.

This paper is structured as follows. Section 2 briefly describes the Australian macroeconomic situation in the second half of the nineteenth century. A brief description of some of the possible theoretical economic mechanisms connecting changes in gold production and domestic prices, and changes in export prices and domestic prices is given in section 3. Details of the structural VAR approach adopted in this paper are given in section 4. Section 5 reports the results of testing for Granger causality, the estimates of the key parameters of the structural VAR, and impulse response functions in response to three shocks, an export price shock, a gold production shock, and a net export shock. Some concluding comments are contained in section 6.

2. Australia's Macroeconomic Situation: 1861-1900

Although Australia was not founded as an independent nation until 1901, the six Australian states are treated as one nation for the purpose of this paper. In the nineteenth century, Australia was a small open economy with exports being mainly of agricultural products, particularly wool. As a result, the Australian economy was particularly sensitive to movements of the export prices of agricultural products. Following the gold rush in the 1850s, Australia was also a large producer of gold. Based on Schmitz's

(1978) estimates of gold production, Australia's share of world gold production was around 30%-35% between 1865-1875, and around 18%-26% between 1880-1900.

Until 1914, Australia was on the gold standard with an exchange rate fixed to the pound sterling. According to Pope (1994), a branch of the British Mint was established in Sydney in May 1855 which fixed the price of gold in Australia at exactly the same price in London. Pope (1994) also notes some other features of Australia's monetary system during this period: (a) prior to 1914, gold coin was the chief form of currency; (b) commercial banks' cash and reserves included gold; (c) prior to 1914 trading banks issues bank notes that were freely convertible into gold; and (d) there were no restrictions on the importing or exporting of gold. There was no central bank in Australia in this period. Capital also flowed relatively freely between Australia and Britain.

Figure 1 depicts the production, export and imports of gold in Australia between 1861 and 1900. As can be seen from this Figure, exports of gold track the production of gold relatively closely. Large increases in the production of gold follow the discovery of gold in Kalgoorlie in Western Australia in 1893 by a few years. Figure 2 depicts changes in the holdings of gold in Australia, when these changes are computed as domestic production of gold + imports of gold – exports of gold.

Figure 3 compares the movement of the Australian consumer price index and the British wholesale price index over the period 1861-1900. In contrast to the deflation observed in Britain between 1870-1890, Australian prices appear to be relatively stable. However, between 1890-1894, the fall in prices is far more severe in Australia than it is in Britain.

Between 1860 and 1889, Australia's real economic growth averaged 4.6% per annum. In contrast, real economic growth in Britain over the same period was 2.0% per annum.

The depth of the recession in the early 1890s in Australia can be seen by contrasting the real economic growth in Australia between 1890 and 1895 of -6.3% per annum with the positive growth rate in Britain of 1.2% per annum. Figure 4 graphs the real economic growth rates of the two countries.

As Figure 5 illustrates, over the period 1860-1894, Australia faced generally falling prices for its exports. The decline between 1890 and 1894 is particularly severe, and is often suggested as being one of the key reasons for the depression in the early 1890s. Export prices recover strongly in the second half of the 1890s. With Australian exports of merchandise principally being agricultural products, it is expected that these movements in export prices would also be reflected to some extent in Australian domestic prices. An eye-ball comparison of the movements of the British wholesale price index in Figure 3 and the export price in Figure 5 suggest their movements are similar. Figure 6 illustrates movements in exports and imports of merchandise (excluding gold). A sharp fall in exports is observed in 1892.

With a fixed exchange rate in operation, and relatively free flow of capital between Australia and Britain, it might be expected that there was little room for Australian interest rates to deviate from those set in Britain. Figure 7 compares interest rate on British consuls, and the Australian six month deposit rate. While the difference between these two rates partially reflects country risk, issuer risk, and maturity risk, the large movements in the Australian deposit rate relative to the British consul rate suggest that despite of free capital flows Australian interest rates could deviate to some extent from British rates.

3. Mechanisms Connecting Gold Production, Export Prices, and Domestic Prices

Australia was on the gold standard throughout the period analyzed in this paper. As

Bordo (1984) indicates, under the gold standard, the expected standard impact of an increase in gold production (or the discovery of gold) in one country is as follows: the increase in gold production is expected to lead to an increase in its money supply leading to a rise in domestic prices. This is called channel 1(a) in this paper. There are a number of offsetting mechanisms that might reduce the need for the adjustment in domestic prices. The rise in domestic prices can be expected to lead to an increase in imports (and possible lower exports), leading to a balance of trade deficit, a gold outflow and a contraction of the money supply (channel 1(b)). In addition, to this route, it is possible that the increase in the money supply leads to an increase in expenditure and income with an impact on imports (channel 1(c)). Alternatively, the rise in the domestic money stock might lead to a fall in interest rates, thus producing a short-term capital outflow and gold outflows (channel 1(d)).

What about the case of an increase in export prices? Given that Australian exports were mainly from the agricultural sector and the prices for these products were set on world markets, a purchasing power parity type link between world prices and Australian prices for these goods could be expected (channel 2(a)). This could be particularly important when the domestic price examined is the consumer price index. A second channel (channel 2(b)) is that the improvement in exports prices leads to an increase in exports, so that initially Australian holdings of gold increase, and the economic mechanism that follows can be expected to be quite similar to the mechanisms in the case of an increase in gold production case of channel 1(a) and the possible offsetting mechanisms. A third channel (channel 2(c)) is that the increase in exports following the rise in export prices will lead to an increase in income, and an increase in the demand for money reducing the need for adjustment of the gold stock held in Australia, and an increase in imports also reducing the need for adjustments of the supply of gold. If exports increased due to an economic boom overseas rather than a change in export prices, channels 2(b) and (c) would also be expected to operate.

Both Pope (1994) and Dick et al. (1996) suggest that the price-specie-flow mechanism (channel 1(a)) provides an inadequate description of Australia's gold movements and trade flows. Both papers highlight the importance of capital flows. It should be noted that the focus of both these papers is balance of payments adjustment, not domestic price or output adjustment.

4. Structural VAR

In this section, a modified version of Calomiris and Hubbard's (1996) structural VAR is described. Given the suggested importance of gold production and variations in export prices in Australia described in section 2, the modification to Calomiris and Hubbard's (1996) involve adding gold production and export prices as variables, omitting the foreign interest rate, and combining exports and imports of merchandise into a single equation for net exports of merchandise.

The seven variables modeled are the log of the export price (PX), gold production (GQ), the domestic interest rate (R), net exports of merchandise (excluding gold) (NX), the log of GDP (Y), the log of the domestic consumer price index (PD), and net additions to the holdings of gold (GA). Details of the variables used in the estimation and their sources are contained in the Data Appendix. These variables are modeled jointly as a vector autoregression, and the innovations from these equations are defined as RPX, RGQ, RR, RNX, RY, RPD, and RGA, respectively.

Suppose that for an $n \times 1$ vector of variables y_t , the structural vector autoregression can be written as

$$A(L)y_t = e_t, \tag{1}$$

where $A(L)$ is a $n \times n$ lag polynomial matrix defined as $A(L) = A_0 + A_1L + A_2L^2 + \dots$, e_t is a $n \times 1$ vector of disturbances with a block diagonal variance-covariance matrix $V = \text{diag}(v_1, \dots, v_n)$. Then, the reduced form vector autoregression is given by

$$B(L)y_t = u_t \quad (2)$$

where $B(L)$ is a $n \times n$ lag polynomial matrix given by $B(L) = A_0^{-1}A(L) = I + B_1L + B_2L^2 + \dots$, $B_i = A_0^{-1}A_i$ ($i=1, 2, \dots$), $u_t = A_0^{-1}e_t$, and u_t has a variance covariance matrix Σ . (In the current case, u_t is assumed to contain RPX, RGQ, RR, RNX, RY, RPD, and RGA.) As a result, $V = A_0 \Sigma A_0'$. Given estimates of the model in (2), and sufficient identifying restrictions on A_0 it is possible to estimate the unknown parameters in A_0 , and obtain estimates of e_t . Rewriting the relationship between u_t and e_t gives $e_t = A_0 u_t$. The first key task is to identify A_0 .

The posited relationships in our seven equation model are an equilibrium output equation for Australia, money supply and demand equations, a gold production equation, an exogenously determined export price, a desired short-run capital flow equation, and a demand function for net exports. The structure assumed is as follows:

$$RPX_t = RPX_t^* \quad (3)$$

$$RGQ_t = a_1 R_t + RGQ_t^* \quad (4)$$

$$RR_t = a_2 RGA_t + RR_t^* \quad (5)$$

$$RNX_t - (RGA_t - RGQ_t) = a_3 RY_t - a_4 RR_t + RNX_t^* \quad (6)$$

$$RY_t = -a_5 RR_t + a_6 RPD_t + a_7 RPX_t + RY_t^* \quad (7)$$

$$RPD_t = a_8 RPX_t + a_9 RR_t - a_{10} RNX_t - a_{11} RY_t + RPD_t^* \quad (8)$$

$$RGA_t = a_{12} RY_t + a_{13} RPD_t - a_{14} RR_t + RGA_t^* \quad (9)$$

All disturbance terms with an asterisk are assumed to be mutually orthogonal. RPX^* is the innovation in the Australian export price, RGQ^* is gold supply shock, RR^* is the money supply shock, RNX^* is the disturbance to desired savings, RY^* is assumed to be a mixture of supply and IS disturbances, RPD^* is the shock to the demand for net exports, and RGA^* is the innovation in Australian demand for money. The parameters a_i are all expected to be positive.

The gold production equation in (4) assumes that increases in interest rates reduce the value of profits from mining gold in the future leading firms to switch production of gold forward from later periods to the current period, thus increasing current production. The specification of the money supply equation in (5) follows Calomiris and Hubbard (1996) in assuming that the money supply responds positively to changes in the domestic interest rate. Calomiris and Hubbard argue that the RR_t^* is likely to capture the effects of domestic money multiplier shocks on the domestic interest rate. The net savings equation in (6) assumes that net savings respond positively to income, and negatively to the domestic interest rate. In line with Calomiris and Hubbard (1996), output assumes a negative impact of the interest rate on the IS curve, and positive price impacts on aggregate supply. The net export function in (8) assumes that exports increase in response to increases in export prices, imports increase in response to increases in domestic prices and income, and falls in domestic interest rates. The money demand function in (9) assumes that money demand increases in response to increases in income and domestic prices and falls in interest rates.

5. Estimates of the VAR

The first step in our procedure is to estimate the reduced form in (2) using data from 1861-1900. The sample period is determined by data availability. Macroeconomic data for Australia generally becomes available for Australia from 1861. A consistent series

for exports and imports of merchandise in this period is only available up until 1900 (see Butlin (1962)). The lag length of the VAR is chosen using a modified LR test, the Schwarz information criterion and Hannan-Quinn information criterion. All these criterion selected a VAR model with one lag². Table 1 contains the results of tests of Granger causality in this seven variable system, and Figure 8 depicts the causality relationships graphically. One interesting finding here is that none of the six other variables Granger cause output or export prices. The latter provides one justification for equation (3). The results of the causality tests in Table 1 suggest there are two variables that directly Granger cause domestic prices, namely export prices and net exports. The direct causal link between export prices and domestic prices is consistent with the purchasing power parity type effect of channel 2(a). Since export prices do not have a direct or indirect causal link to income, the causal link connecting the export price and domestic price via net exports would appear to be more consistent with channel 2(b) than channel 2(c). However, there is no direct causal impact on gold holdings. In contrast, gold production does not directly Granger cause domestic prices, rather the causal connection between gold production and domestic prices is through interest rates and net exports which provides some support for channel 1(c). The direct causal connection between export prices and gold production is a little difficult to explain.

The results of estimating (3)-(9) are as follows (absolute t-values appear in parentheses):

$$RGQ_t = -0.257RR_t + RGQ_t^* \quad (4^*)$$

(1.85)

$$RR_t = 0.999RGA_t + RR_t^* \quad (5^*)$$

(0.40)

² Given the well known poor power properties of tests for unit roots and cointegration with small sample sizes, the pragmatic decision was made not to test for unit roots and cointegration, but rather use a levels model for the purpose of this paper.

$$RNX_t - (RGA_t - RGQ_t) = -0.278RY_t - 1.454RR_t + RNX_t^* \quad (6^*)$$

$$(0.01) \quad (0.71)$$

$$RY_t = -0.050RR_t + 1.718RPD_t + 0.013RPX_t + RY_t^* \quad (7^*)$$

$$(0.37) \quad (0.53) \quad (0.03)$$

$$RPD_t = 0.258RPX_t + 0.027RR_t - 0.006RNX_t - 869RY_t + RPD_t^* \quad (8^*)$$

$$(0.73) \quad (0.35) \quad (0.46) \quad (0.50)$$

$$RGA_t = -8.43RY_t - 23.15RPD_t - 2.997RR_t + GA_t^* \quad (9^*)$$

$$(0.38) \quad (0.41) \quad (0.69)$$

There are seven overidentifying restrictions in this model, and a test for the validity of these overidentifying restrictions suggests they should be strongly rejected (p value=0.0008). However, it was not possible to find a model that passed the overidentification test, and had a structure that made economic sense. Out of the fourteen estimated coefficients, ten have estimated coefficients with a sign that is consistent with a priori expectations. As can be seen from the small size of all the absolute t-values, none of the estimated coefficients are precisely measured.

Using the estimates in (4*)-(9*), and estimates of the residuals in the reduced form VAR, it is possible to compute estimates of the orthogonal structural form residuals, and use these residuals to compute impulse response functions. The results for three shocks, an export price shock (Panel A), a gold production shock (Panel B), and a net export shock (Panel C), are presented in Table 2. In addition to presenting the estimated impact of these three shocks on the seven variables in the vector autoregression, the implied impacts on net exports of gold and capital inflows are also presented in Table 2. For these implied impacts, net exports of gold are calculated as $-(\text{Gold Holdings} - \text{Gold Production})$, and “capital inflows” are calculated as $-\text{Net Exports of Merchandise and Gold}$. It is important to note that output does not respond significantly to any of these shocks, and domestic prices only respond significantly to the export price shock.

Panel (A) presents the results for the impact of an export price shock. The significant impacts on gold production, net exports and domestic prices are consistent with the causality observed in Table 1. As with the causality tests, the strong link between export prices and domestic prices probably reflects the fact that the domestic price used is a consumer price index and export prices are dominated by the prices of agricultural products giving rise to a purchasing power parity connection (channel 2(a)). The rise in domestic prices could lead to a switch to imports reducing net exports and requiring a compensating capital inflow in response to higher interest rates. What is surprising is that net exports fall and fall significantly. This fall in net exports is the opposite of what channels 2(b) and 2(c) predict. The reduction in gold production in response to a rise in interest rates probably reflects the negative estimated parameter in equation (4*).

In response to a gold production shock, the results in Panel (B) of Table 2 suggest there is no significant change in holdings of gold in Australia, domestic prices or output. The mechanism for this in the short-term would appear that net exports fall (imports increase) requiring a net outflow of gold. Reflecting what is observed in Figure 1, estimated gold production and implied gold exports are very similar. The gold production shock would appear to be quite persistent. As interest rates fall, a capital outflow is generated which acts to ensure that domestic holdings of gold do not change significantly. These results would appear to support the capital flow mechanism of channel 1(d).

Panel (C) of Table 2 would appear to indicate that net export shocks do not significantly affect any variables in either the short or medium term. (This may suggest that the net export shock has not been identified correctly.) The actual size of the impact on domestic prices is very small which would appear to be inconsistent with channel 2(b). If anything, there is a fall rather than a rise in income rejecting channel 2(c). In the

second year, the next export shock raises net exports, and this is offset by capital outflows despite a very slight rise in the interest rate.

6. Conclusion

Using annual macroeconomic data for Australia for the period 1861-1900, this paper has sought to examine the factors influencing movements of the domestic consumer price index with a particular emphasis on the role of export prices and gold production. Gold production is found not to directly cause Granger cause prices, and the estimated impacts of gold production shocks suggest they do not significantly influence domestic prices. This suggests that Australia's escape from deflation in the mid-1890s cannot be attributed to increases in the production of gold as a result of gold discoveries in Western Australia. In contrast, export prices significantly cause domestic prices, and export price shocks are found to lead to significant increases in domestic prices. The mechanism connecting these two prices would appear to be a purchasing power parity type of mechanism. Finally, the model presented does not help in understanding the movements of real output in this period.

Figure 1: Exports, Imports and Production of Gold

Million Pounds

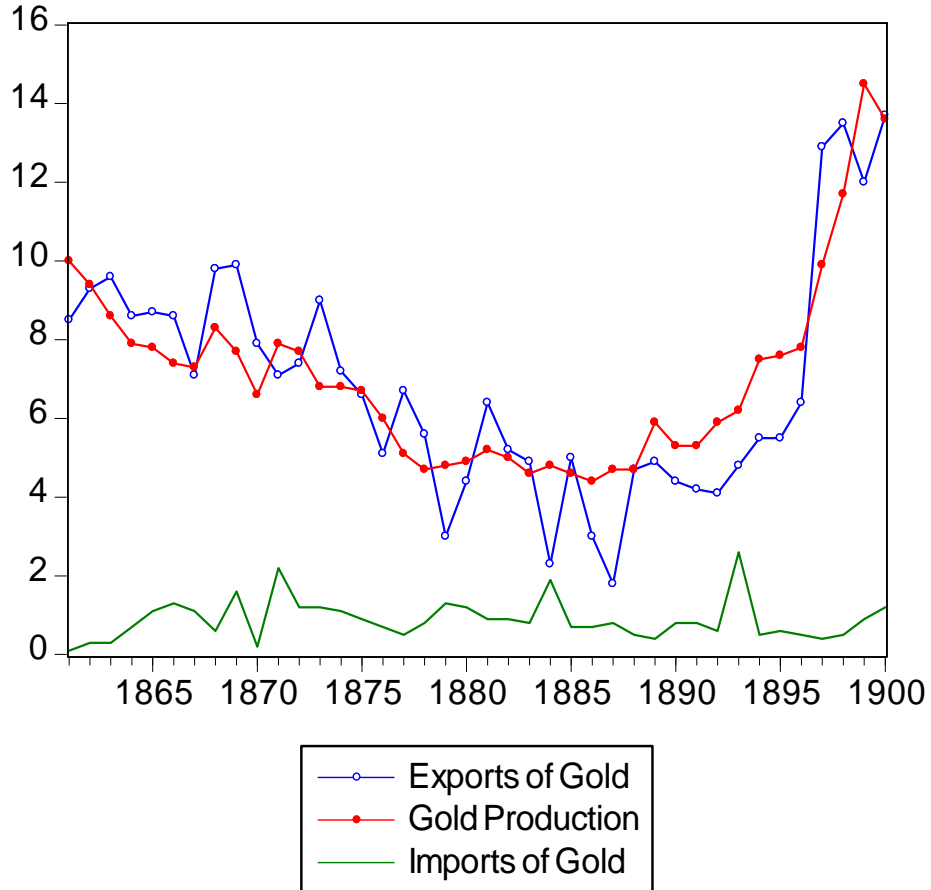


Figure 2: Changes in Holdings of Gold in Australia

Million Pounds

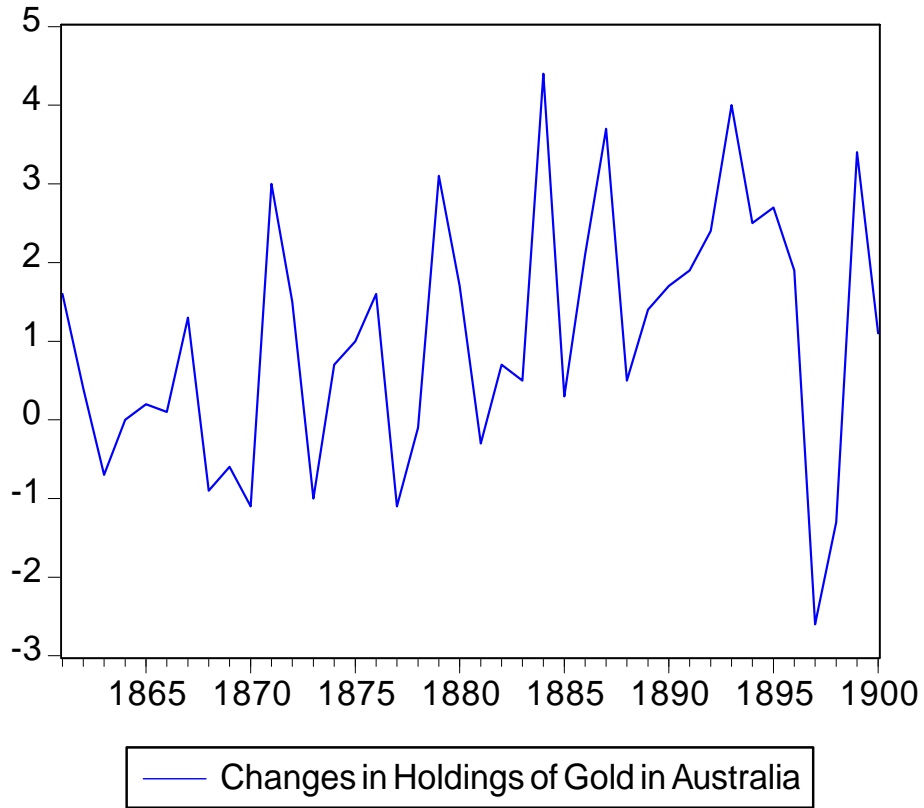


Figure 3: Price Movements in Australia and Britain

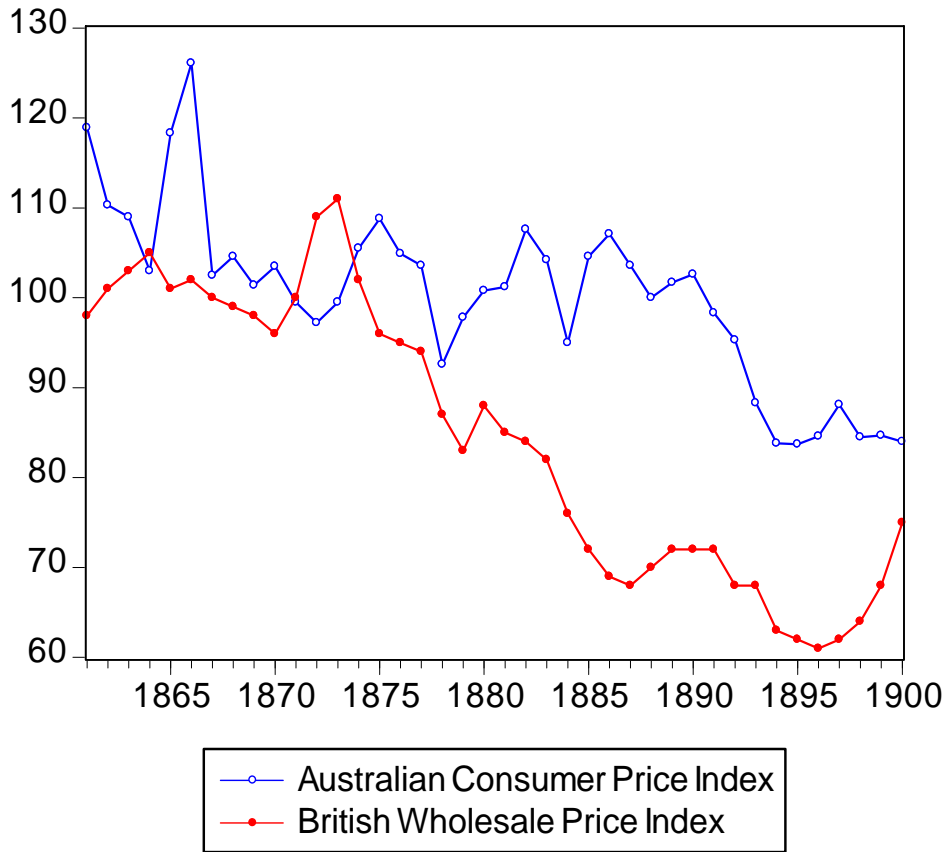


Figure 4: Real Economic Growth in Australia and Britain

%

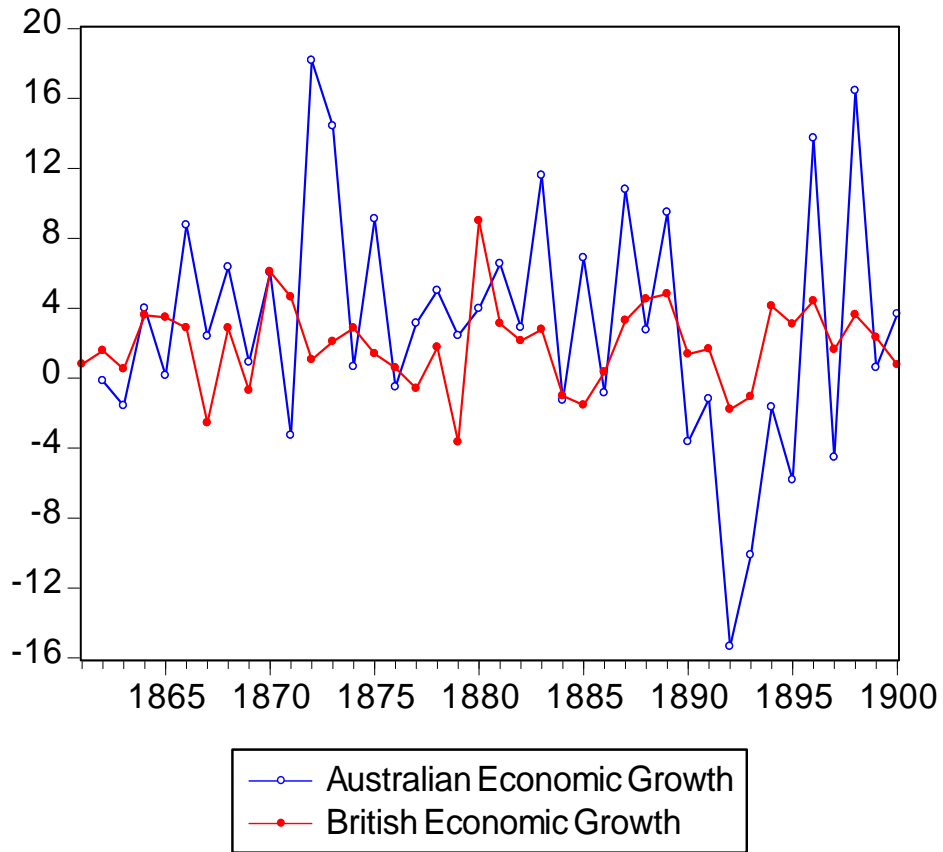


Figure 5: Australian Export Price Movements

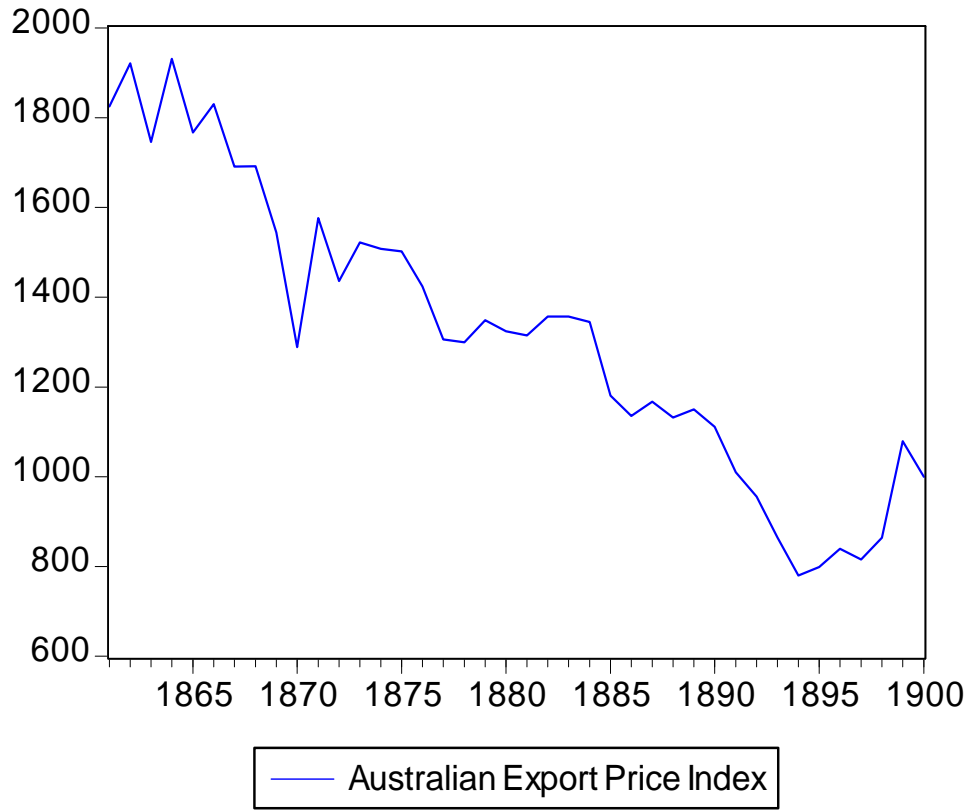


Figure 6: Imports and Exports of Merchandise

Million Pounds

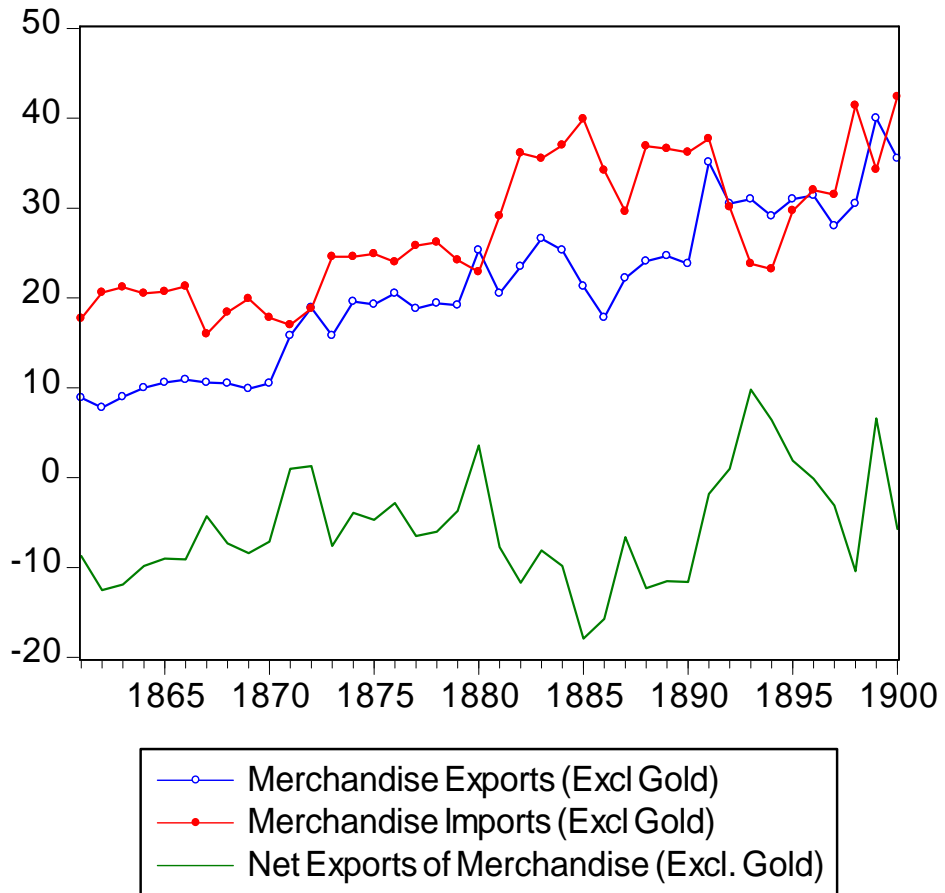


Figure 7: Australian and British Interest Rates

%

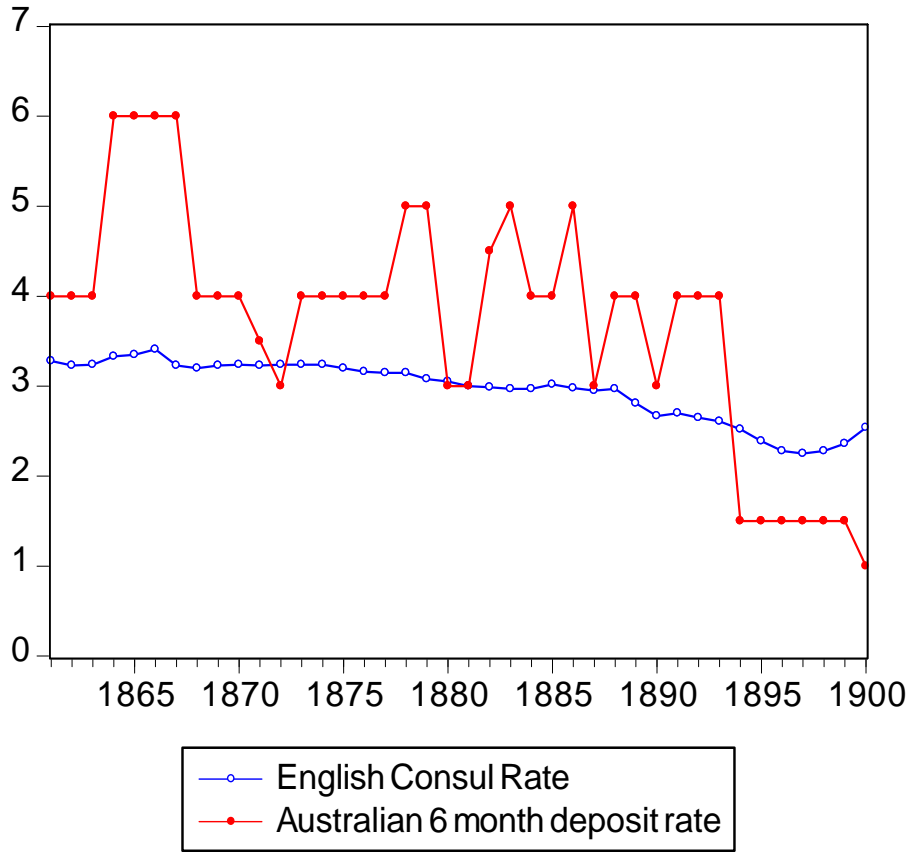


Figure 8: Causality Relationships Among Variables



Notes:

- (1) The causality relationships presented here are based on the results in Table 1, and using a 5% significance level to test for causality.
- (2) A ----> B indicates Granger causality from A to B.

Table 1: Causality Tests

Causing Variable	Caused Variable						
	Export Price	Gold Production	Interest Rate	Net Exports	GDP	Domestic Prices	Gold Additions
Export Price	na	0	0.09	0.01	0.41	0	0.08
Gold Production	0.98	na	0.036	0.54	0.48	0.13	0.39
Interest Rate	0.63	0.06	na	0.03	0.24	0.93	0.01
Net Exports	0.36	0.44	0.47	na	0.59	0.02	0.79
GDP	0.19	0.29	0.99	0.31	na	0.79	0.36
Domestic Prices	0.74	0.38	0.28	0.88	0.46	na	0.67
Gold Additions	0.1	0.19	0.11	0.65	0.8	0.34	na

Note: Figures in the table are p-values for the Wald tests of the null hypothesis that the causing variable does not Granger cause the Caused Variable in the seven variable VAR. A figure less than 0.05 indicates Granger causality at the 5% significance level.

Table 2: Impulse Response Functions Using Estimates of Structural VAR

(A) Impulse Response to an Export Price Shock

	Estimated							Implied	
	Export Price	Gold Production	Interest Rate	Net Exports	GDP	Domestic Prices	Gold Holdings	Net Gold Exports	Capital Inflows
1st Year	0.074*	0.017	-0.061	0.007	0.013	0.006	-0.061	0.078	-0.085
2nd Year	0.058*	-0.280*	0.160	-1.769*	0.020	0.017*	-0.346	0.066	1.703
3rd Year	0.054*	-0.424*	0.326*	-1.697*	0.022	0.023*	-0.083	-0.341	2.038
4th Year	0.045*	-0.553*	0.346*	-1.278	0.021	0.024*	0.087	-0.640	1.918

(B) Impacts of Gold Production Shocks

	Estimated							Implied	
	Export Price	Gold Production	Interest Rate	Net Exports	GDP	Domestic Prices	Gold Holdings	Net Gold Exports	Capital Inflows
1st Year	0.000	0.635*	-0.013	-0.630*	0.003	0.001	-0.012	0.647	-0.017
2nd Year	0.002	0.666*	-0.088	-0.113	0.000	-0.002	0.088	0.578	-0.465
3rd Year	0.001	0.654*	-0.136*	-0.127	-0.001	-0.004	0.007	0.647	-0.52
4th Year	0.002	0.644*	-0.137*	-0.215	-0.001	-0.004	-0.042	0.686	-0.471

(C) Impacts of Net Export Shocks

	Estimated							Implied	
	Export Price	Gold Production	Interest Rate	Net Exports	GDP	Domestic Prices	Gold Holdings	Net Gold Exports	Capital Inflows
1st Year	0.000	-0.067	0.243	-0.029	-0.052	-0.023	0.243	-0.31	0.339
2nd Year	-0.003	0.054	0.039	0.688	-0.049	0.000	0.103	-0.049	-0.639
3rd Year	-0.001	0.061	0.051	0.492	-0.047	-0.003	-0.074	0.135	-0.627
4th Year	0.003	0.088	0.029	0.376	-0.045	-0.003	-0.078	0.166	-0.542

Note:

(1) An asterisk indicates that the impact is significant at the 5% level.

(2) In each case, the response is to a one standard deviation innovation in the structural shock.

DATA APPENDIX

The data used in this paper are obtained from the following sources:

Britain

Yield on 3% British Government Consols: Homer & Sylla (1991, Table 19)

British Wholesale Price Index: Overall Price Index in Mitchell and Deane (1962, Pages 474-475)

British Real Gross Domestic Product: Output data index number in Feinstein (1972, Table 6 (Index number of gross domestic product at constant factor cost)).

Australia

Australian Consumer Price Index, Series B6 in McLean (1999, Table A1)

Australian Gold Production: Butlin (1962, Table 247)

Australian Exports of Gold & Specie: Butlin (1962, Table 247)

Australian Imports of Gold & Specie: Butlin (1962, Table 248)

Deposit Rate on 6 month Trading Bank Deposits: Butlin et al. (1971, Table 51)

Australian Gross Domestic Product at 1910/11 Constant Prices: Butlin (1985, Table 9)

Australian Total Merchandise Exports: Butlin (1962, Table 247)

Australian Total Merchandise Imports = Imports from UK + Imports from rest of the world-Imports of Gold and Specie: Butlin (1962, Table 248)

Australian Export Price Index: Vamplew (1987, Table ITFC81-83)

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