

AUSTRALIA'S MEDIUM-RUN EXCHANGE RATE: A MACROECONOMIC BALANCE APPROACH

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Abstract

We analyse the determinants of Australia's exchange rate in terms of the approach introduced by Williamson (1983), based on the simultaneous attainment of internal and external balance. Internal balance implies that the economy is operating at its supply potential with no inflationary pressures. External balance is characterised as the sustainable net flow of resources (corresponding to a current account to GDP ratio) between countries when they are in internal balance. The approach provides estimates of the medium-term exchange rate associated with a given current account position, although the estimates are highly sensitive to variations in key parameters.

JEL Classification Numbers: F31, F32

Keywords: current account, equilibrium exchange rates, terms of trade

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1. Introduction

Economists have suggested a large number of – sometimes competing – theories of equilibrium exchange rate determination, partly reflecting the mixed empirical support most of these theories have. Success in explaining the behaviour of exchange rates depends importantly on the time horizon.¹ Over the short term – up to a year or so – Meese and Rogoff (1983) have shown that a random walk explains exchange rate behaviour at least as well as fundamental-based equilibrium concepts do. Fundamental-based concepts, such as purchasing power parity, have more favourable evidence over the long run. Similarly, the macroeconomic balance approach, which is based on the relationship between the current account and the exchange rate, is an explicitly medium-run concept. This paper uses the macroeconomic balance approach and applies the concept to Australian data.²

The macroeconomic balance approach, which is based on the simultaneous achievement of internal and external equilibrium, goes back to Meade (1951) and Swan (1963). Internal balance is reached when economies are operating at their supply potential, while external balance is defined as an ‘appropriate’ or target capital account position. The equilibrium exchange rate is defined as the level of the exchange rate that is consistent with medium-term macroeconomic equilibrium.

¹ For a summary, see e.g., MacDonald (2000) and Driver and Westaway (2001).

² A number of studies have related Australia's long-run exchange rate to the current account, the terms of trade and capital flows, which are variables included in the macroeconomic balance approach (see e.g., Blundell-Wignall, Fahrer and Heath (1993)). The macroeconomic balance approach was used by Isard and Faruquee (1998) and Isard *et al* (2001) in their Internal-External-Balance models in a multilateral framework. They focus on developing a target capital account model based on optimal savings and investment decisions.

Using this approach, a medium-term equilibrium exchange rate can be estimated for any current account balance. This equilibrium is therefore a flow equilibrium. A sustainable current account balance, however, is not necessarily a stock equilibrium: such an equilibrium, which could be reached over the long run, implies a stable net-foreign asset to GDP ratio. This also implies that the medium-run equilibrium exchange rate consistent with a flow equilibrium can change over time, and often does so.

At any point in time, actual values of the exchange rate will reflect influences of equilibria over all three horizons. Short-run movements can reflect changes in 'market equilibrium rates', that is, the exchange rate that balances demand and supply in the foreign exchange market. Medium-run and long-run changes might reflect convergence to flow equilibria and stock-flow equilibria. We would therefore not necessarily expect that the actual exchange rate is at the medium- or long-run equilibrium level at any specific date. While we would expect convergence forces to bring the exchange rate to equilibrium over time, the macroeconomic balance approach is silent about the adjustment forces that might bring us there.

Section 2 explains the macroeconomic balance approach in more detail. An equation for the underlying current account for Australia is estimated in Section 3. Section 3.3 illustrates the macroeconomic balance exchange rate based on this estimate, with a sensitivity analysis in Section 3.4. Section 4 concludes.

2. Modelling Macroeconomic Balance

Williamson (1983) adopted the macroeconomic balance approach to derive estimates of exchange rates consistent with internal and external balance, which he labelled 'fundamental equilibrium exchange rates'. This concept has sometimes been described as a current account theory of exchange rate determination, however, Wren-Lewis describes it as not a theory, but:

...a method of calculation of a real exchange rate which is consistent with [macroeconomic balance]. (Wren-Lewis 1992, p 75)

The approach is rooted in the balance-of-payments identity:

$$\text{Capital Account} = \text{Current Account} = CA(E, P^*, P, Y, Y^*, Z) \quad (1)$$

The right-hand side of Equation (1) is the current account CA which consists of the trade balance, net foreign income flows and net transfers. For Australia, most of the volatility in the current account is driven by changes in the trade balance. The current account balance in Equation (1) depends explicitly on the real exchange rate ($E \cdot P / P^*$), which affects the trade balance via the prices and volumes of imports and exports and that part of net foreign investment income that is denominated in foreign currency. It also depends on levels of domestic and foreign incomes, Y and Y^* , as well as a variety of other factors Z that may shift the current account balance over time. The capital account is equal to the current account by definition.

2.1 Internal and External Balance

The macroeconomic balance approach rests on two concepts: internal balance and external balance.

The economies are in internal balance when output is at potential and current exchange rate effects have worked themselves through the system; that is, pass-through is complete. Both conditions reflect the medium-run nature of the concept. We define the current account consistent with these conditions as the ‘underlying current account’. In order to evaluate the underlying current account, the long-run elasticities of the current account with respect to the exchange rate and output have to be estimated. Internal balance is then reached when output is set to trend output. The exchange rate elasticity of the current account is needed to assess how much the current exchange rate has to move in order to bring the underlying current account to the target level.

External balance is achieved when the underlying current account is equal to the value of the target capital account, which is characterised as the sustainable desired net flow of resources between countries when they are in internal balance. The capital account is identically equal to the excess of domestic savings over investment. Therefore, Isard and Faruquee (1998) and Isard *et al* (2001) explicitly

model the target capital account dependent on factors that influence optimal savings and investment decisions. Amongst others, these factors are the consumption smoothing decisions of the agents (i.e., the savings ratio), demographics (i.e., the dependency ratio), the relative fiscal position and capital needs determined by the development stage.

The macroeconomic balance approach models exchange rate equilibrium as the level that generates an underlying current account equal to the target capital account when the domestic and foreign economies are in internal equilibrium.

It should be noted that this approach is based on a medium-term equilibrium which is likely to change over time. One reason is that the factors determining the target capital account, such as demographics or fiscal policy, can change over time, which would imply a corresponding change in the exchange rate. Another reason is that the underlying current account for a country might change both over time and relative to other countries. We treat only changes in output (relative to potential) and the exchange rate as endogenous to our model. Any change in an exogenous variable can therefore change the underlying current account (some examples are discussed in Section 2.3). This implies that the value of the equilibrium exchange rate will depend on the time period in which it is calculated.

2.2 The Macroeconomic Balance Approach in Three Steps

The macroeconomic balance approach can be implemented in three steps:

1. Choose a sustainable, or target, capital account KA_{target} .
2. Derive the underlying current account $CA(E, Z) = CA(E, \bar{Y}, \bar{Y}^*, Z)$ where \bar{Y} and \bar{Y}^* are potential outputs and Z is a set of other exogenous variables.
3. For each assumed value of KA_{target} , solve for the exchange rate that satisfies $KA_{target} = CA(E, Z)$.

Step 1: The target capital account

The target capital account is usually arrived at judgementally, taking positions on optimal savings and investment decisions. Often it is taken as the medium-run average of the actual current account. Or it is explicitly modelled as in Isard *et al* (2001) and Williamson and Mahar (1998). However, in this paper we avoid modelling the target capital account and instead provide a range of estimates of equilibrium exchange rates associated with alternative assumptions about the capital account position.

Step 2: The underlying current account

Since we take an agnostic view on the target capital account, we can move straight to Step 2. We decompose the current account into trade balance ($X-M$), net foreign income NID ³ (which consist mainly of net investment income arising from interest, profit and dividends), and net transfers NT . We model these three building blocks separately to identify the elasticities of each component to changes in the exchange rate and to output.

$$CA = X(E, Y^*) - M(E, Y) - NID(E) + NT \quad (2)$$

The second and third component of the current account, net investment income and net transfers are modelled in the simple way suggested by Wren-Lewis and Driver (1998), henceforth WD. Investment income derived from assets denominated in foreign currency will move directly with the exchange rate. Net transfers are assumed to be independent of demand or the exchange rate.

The first component, the trade balance, is the heart of the underlying current account equation and requires more modelling effort. The focus of our study is very similar to that of WD, in that they concentrate on estimating the price and income elasticities of the trade flows that underlie the trade balance. We expect exports to increase if the exchange rate E depreciates or if world demand increases. Imports will increase with domestic demand or when the exchange rate appreciates. The trade balance will thus increase when the domestic currency

³ Note that the net foreign investment income in Australia is usually shown as a deficit number. Therefore we have to subtract the NID term in Equation (2).

depreciates. So much for the theory. Goldstein and Khan (1985) have shown that estimated trade elasticities often turn out to be effectively zero. Or worse, they might have the wrong sign. In practice, therefore, elasticities are often imposed for some equations, as for example in WD or Isard *et al* (2001).

Once we have estimated all trade elasticities we can use them in Equation (2) to model the underlying current account as a function of the exchange rate E . We evaluate this function after setting domestic and foreign output to their trend levels and setting all exogenous variables to their actual values at specific dates.

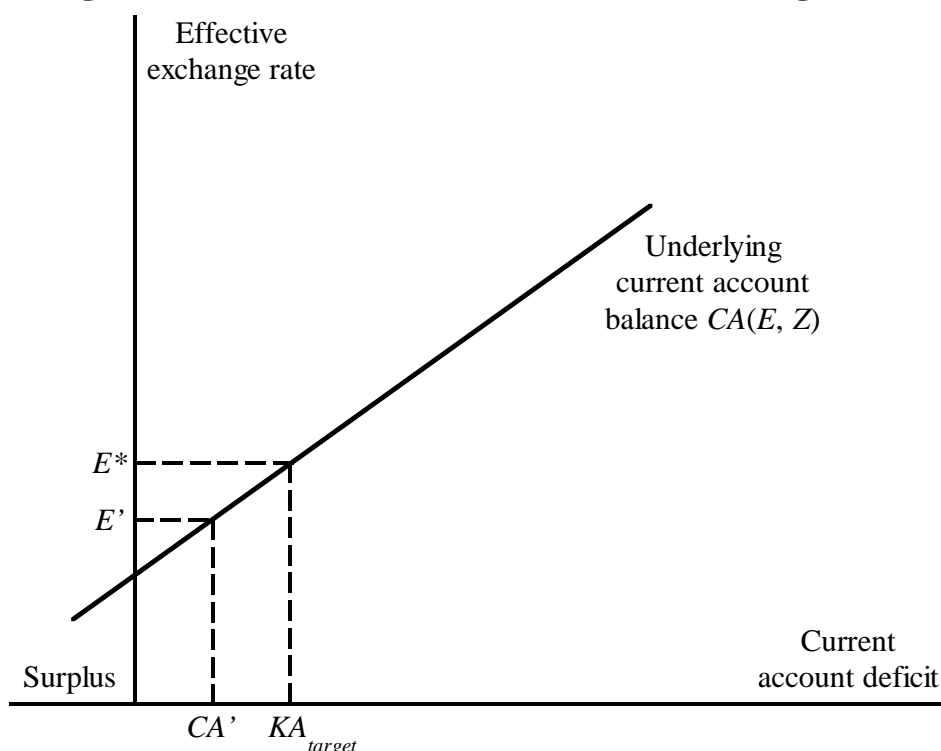
To make useful comparisons over time and between countries, the current account is usually modelled as a proportion of nominal GDP, $P \cdot Y$. Equation (2) then becomes:

$$\frac{CA}{PY} = \frac{1}{PY}(X(E, Y^*) - M(E, Y)) - \frac{1}{PY}NID(E) + \frac{1}{PY}NT \quad (3)$$

Step 3: Solving for the exchange rate

Step 3 is straightforward. Once Equation (3) is estimated and output gaps are set to zero, it is then possible to calculate the level of the exchange rate E which equates $CA(E)$ with the target capital account. Figure 1 summarises the relationship between the equilibrium exchange rate and the assumed capital account position: E^* would be the equilibrium which corresponds to the target KA .

If the exchange rate was E' , Step 2 would identify CA' as the underlying current account position. CA' will be different from the observed current account to the extent that output gaps are not zero. Step 3 would then tell us how much the exchange rate has to change to equilibrate the underlying current account with the target KA . The necessary change is broadly the difference between E' and E^* .

Figure 1: The Macroeconomic Balance Exchange Rate

Source: Isard and Faruquee (1998)

2.3 Limitations of the Macroeconomic Balance Approach

The macroeconomic approach has – like every concept of calculating equilibrium exchange rates – a number of shortcomings.

Some limitations relate to the implementation of the approach. Firstly, judgement is necessary to decide on the target capital account. Secondly, some trade elasticities are notoriously difficult to estimate, and low exchange rate elasticities of the trade balance may imply implausibly high estimates of the sensitivity of the equilibrium exchange rate to the assumed capital account position.

A more conceptual problem is that the underlying current account, and therefore the equilibrium exchange rate, might change over time as a result of changes in

other variables that determine Equation (3).⁴ WD distinguish four sources of such changes. First, there may be a trend in some components of trade, such as a declining (world) export share. Second, trend rates of GDP growth at home and abroad might differ. This can imply a different rate of change for exports and imports, and thus a change in the trade balance. Third, estimated income elasticities may be different for exports and imports. Then, even if domestic output grows at the same trend rate as foreign output, the trade balance (and therefore the underlying current account) would change. Fourth, the approach does not impose a stock equilibrium. A non-zero current account target implies a continuing change in the net foreign asset position. For instance, a country that runs an underlying current account deficit lowers debt interest receipts and further increases the current account deficit (the reverse holds for a country in surplus). This would require a trend depreciation unless GDP grows at the same rate as the net foreign asset position.

Finally, the approach does not explain the dynamics of the adjustment to the macroeconomic balance exchange rate. Taking the functional relationship in Equation (1) literally would imply a causal relationship from the target capital account to the exchange rate. However, as discussed earlier, the macroeconomic balance methodology involves calculating an exchange rate that is consistent with internal and external equilibrium – it is silent about the dynamics of the adjustment. The exchange rate is merely the relative price that facilitates the adjustment of the underlying current account to the target capital account.

3. Empirical Estimates

This section presents empirical estimates of the parameters required to implement the approach set out in Section 2.2. As discussed there, we proceed directly to Step 2, since we evaluate the macroeconomic balance exchange rate as a function of the target capital account. In Section 3.1 we discuss the underlying current account equation. The coefficients of this equation are functions of trade

⁴ There are two ways to address this problem. WD make their estimates period-specific and calculate them for different years. Isard and Faruquee (1998) account for the ‘drift’ due to changes in non-modelled variables by correcting the intercept of the trend current account in each period.

elasticities, which are estimated in Section 3.2. In Section 3.3 we evaluate Step 3 and derive estimates of exchange rate equilibria under a range of alternative assumptions and time periods. Confidence intervals (Section 3.4) illustrate the degree of uncertainty around these estimates.

3.1 The Underlying Current Account

Our first task is to model the underlying current account. We are interested in the answer to two questions. How does the current account change if output moves to potential? And how does the current account change if the exchange rate changes? We are primarily interested in the long-run impact of these variables; that is, once pass-through is complete.

Following Equation (2), we model the Australian current account as the sum of net foreign income, the trade balance, and net transfers. Let us consider each component in turn. Net foreign income accounts for a large part of Australia's current account deficit (on average, 80 per cent in 1997–2001). Net foreign income consists mainly of net investment income, and therefore we ignore net compensation from foreign employment in our model. Net investment income is the interest income from net foreign asset holdings, which in Australia's case are net foreign liabilities. The main effects of exchange rate changes are valuation effects, which only apply to the share of net interest income that is denominated in foreign currency. We assume that there is no effect from closing the output gap on this term (for more details see Appendix B). Net investment income, while being an important part of Australia's current account, is relatively stable through time.

Most of the movement in the current account stems from changes in the trade balance. Because it is strongly influenced by movements in output and the exchange rate, our econometric analysis focuses on this component. For the trade balance we use a disaggregated model of trade, described in more detail in Section 3.2. Finally, net transfers, which account for only a small fraction of the current account, are modelled using a simple time trend. They are therefore assumed to be independent of changes in the exchange rate or in the output gap.

Once we have estimated the trend trade balance we can obtain the empirical equivalent to Equation (3), the underlying current account, which can then be solved for the exchange rate, conditional on the assumed target capital account.

3.2 Empirical Estimates of Trade Elasticities

We estimate the trade balance for Australia using data up to 2001:Q4. The starting points of the series vary from 1971:Q3–1984:Q3 (see Appendix A for more details on the data). Since the methodology is cast in terms of medium-run relationships, the time series properties of the data must be taken into account. We tested the data and found that they are non-stationary over the sample period (details in Appendix C). A cointegration framework is therefore the appropriate methodology.⁵

Particular care is taken to gauge the effects of the exchange rate on prices and volumes. This requires some clarification of the choice of the exchange rate. In principle, the macroeconomic balance approach identifies the *real* exchange rate and therefore most studies solve for a real exchange rate equilibrium level. The implied nominal exchange rate can then be calculated for given relative prices in a specific period. With our disaggregated approach to modelling the trade balance, we have multiple real exchange rates and therefore solve directly for the *nominal* effective exchange rate (the TWI, abbreviated with E^{twi}) instead.⁶

In principle, one could estimate the impact of changes in the exchange rate and output on the trade balance using an aggregate model, for instance, with one equation for aggregate exports and another for aggregate imports. However, we found it difficult to uncover a statistically significant exchange rate effect for these aggregate equations. Where we did, the coefficient was often unstable or had the ‘wrong’ sign. We therefore opted to use a disaggregated approach, following much of the existing literature on trade equations for Australia. We model goods and services separately for both exports and imports. Moreover, because we find it very difficult to model aggregate goods exports, we break this particular category up

⁵ In the first instance we relied on the Johansen procedure to test the cointegration relationship. We also compared the results to ECM and OLS estimates. Appendix C contains the details.

⁶ WD solve for a real exchange rate, but one has then to estimate (or impose) a relationship between the different real exchange rates used for the estimation of the trade equations.

into the three subcategories of rural goods' exports, resource goods' exports and manufactured goods' exports. For each category there is potentially a volume and a price equation.

Trade equations are best thought of as arising from a demand and supply system. Therefore, there are simultaneity issues that are relevant for our estimation. Most of our estimated equations assume that Australia is a price maker or price taker, and thus eliminate either demand or supply from the system. Table 1 shows how this is applied to the different trade components. Clearly, there is no price equation to estimate when we assume either polar assumption of price making or price taking.⁷

Table 1: Estimation Assumptions			
Aggregate	Price taker or price maker?	Estimated relationship	Price or volume estimated?
Exports			
Agricultural	Price taker	Local supply	Volume
Resource	Price taker	Local supply	Volume
Manufactured	–	Reduced form	Price and volume
Services	Price maker	World demand	Volume
Imports			
Goods	Price taker	Local demand	Volume
Services	–	Local demand and price	Price and volume

In what remains of this section, we illustrate our estimation techniques using the first two trade components in Table 1 – agricultural and manufactured exports. For agriculture, we assume that Australian producers are price takers. This allows us to identify the supply curve since the demand curve is given by the world price. Similar simplifying assumptions of price taking or price making are used for resource exports, service exports and goods imports. For manufactures, we avoid the simplifying assumption and estimate the reduced form of a price and volume system. For service imports, we estimate both a price and a volume equation, but they are not explicitly derived from a reduced form.⁸

⁷ We are grateful to Tony Webber for helping us clarify these simultaneity issues.

⁸ The service import equations do not work very well; see Appendix B.

3.2.1 Agriculture

We model the supply curve using real GDP to account for capacity constraints and subsidies to capture any supply shocks. Under the maintained hypothesis that Australia is a price taker, world output has no direct effect on export volumes.⁹

We estimate the long-run relationship using a VECM with four lags (Equation (4)). For illustration purposes we only report the long-run coefficients. The standard deviations are below the point estimates of the coefficients in brackets. Lower case variables are in logs.

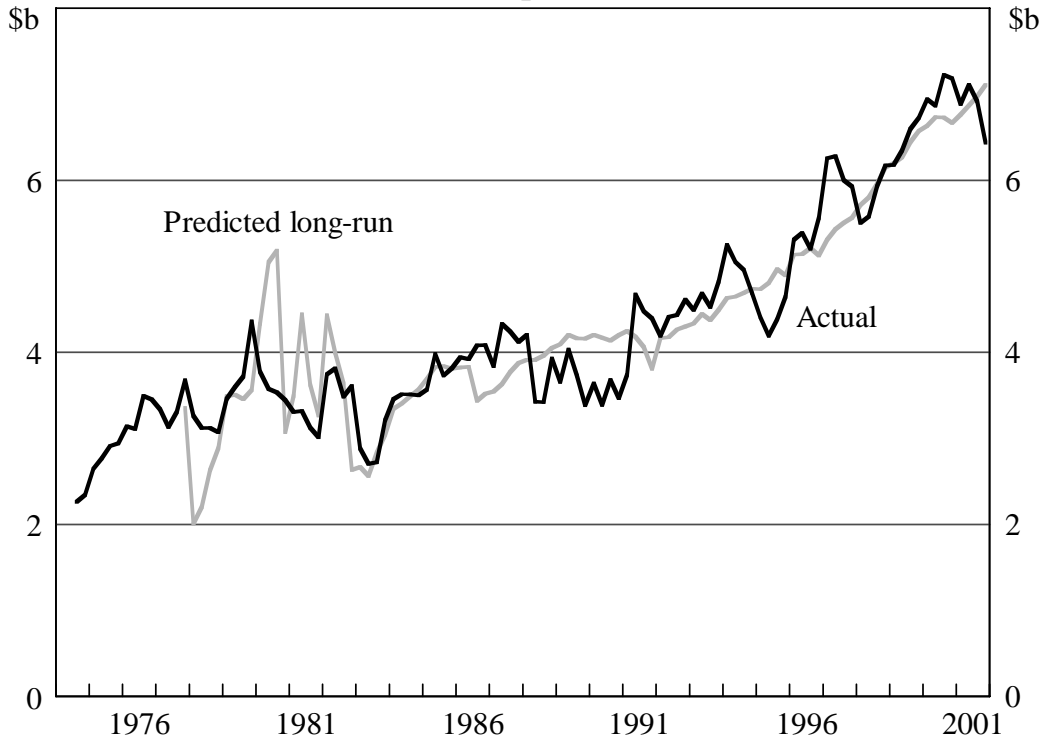
$$x_{agr} = -10.3 - 0.2 s_{agr} + 1.7 y \quad (4)$$

(0.04) (0.2)

where x_{agr} denotes the volume of agricultural exports, s_{agr} are agricultural subsidies not included in gross value of production, and y is Australian real GDP. The results are illustrated in Figure 2.

⁹ This is not as unrealistic as it sounds. The effect of world output on export volumes comes through commodity prices.

Figure 2: Agricultural Export Volumes
1995 prices



3.2.2 Manufactures

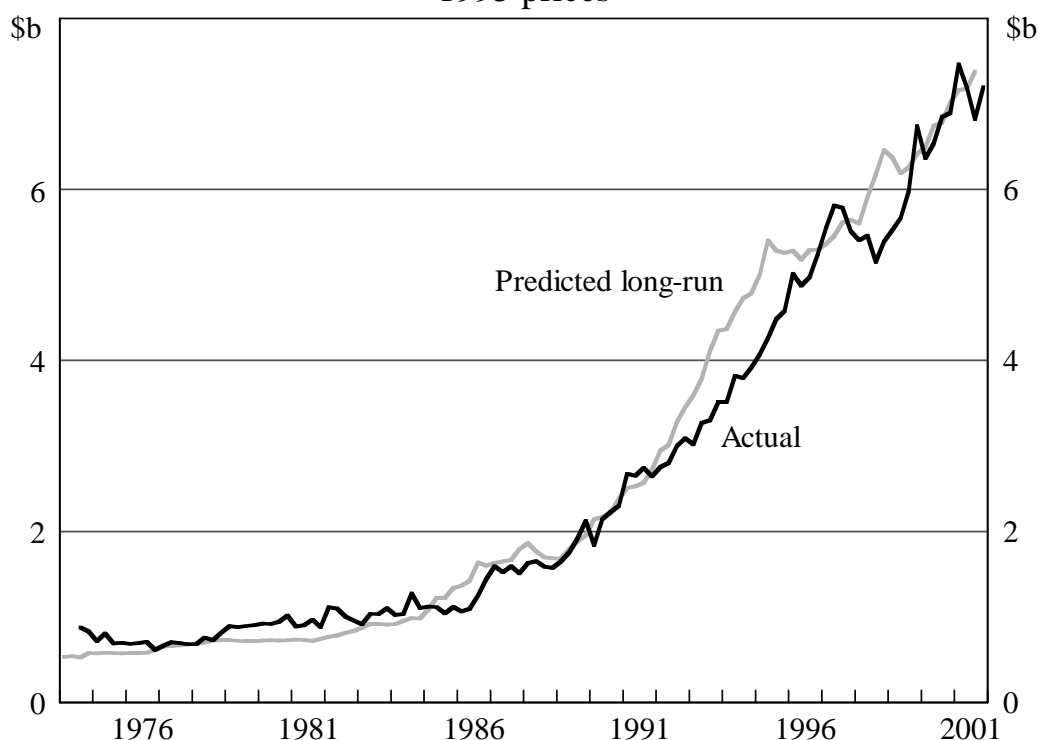
For manufactures, we do not want to impose price taking or price making *a priori*. We therefore set up a demand and supply equation for manufactures in the world market and obtain the reduced forms. Variables are natural logarithms and constants are ignored for the exposition. Prices are in US\$, all coefficients are positive, and zero price homogeneity is imposed.

$$x_{man}^s = \beta_1 p_x - \beta_1 (p + e^{twi}) + \beta_2 t_{1986} \quad (5)$$

$$x_{man}^d = -\beta_3 p_x + \beta_3 p_w + \beta_4 t_{1986}$$

The supply equation says that Australian producers may sell their goods onto the world market for a US\$ price of p_x or sell it locally for a price (expressed in US\$) of $p + e^{twi}$. On the demand side, overseas consumers can buy the Australian good for p_x , or a world good (a consumption substitute) for p_w . The pronomeral t_{1986} represents other supply and demand influences. Following Menzies (1994), the

Figure 3: Manufactured Export Volumes
1995 prices



We estimate the reduced form expression for the price of manufactured exports, with the restriction imposed that the price coefficients sum to unity, and are non-negative. We used Non-linear Least Squares (NLS) to impose the latter restriction:

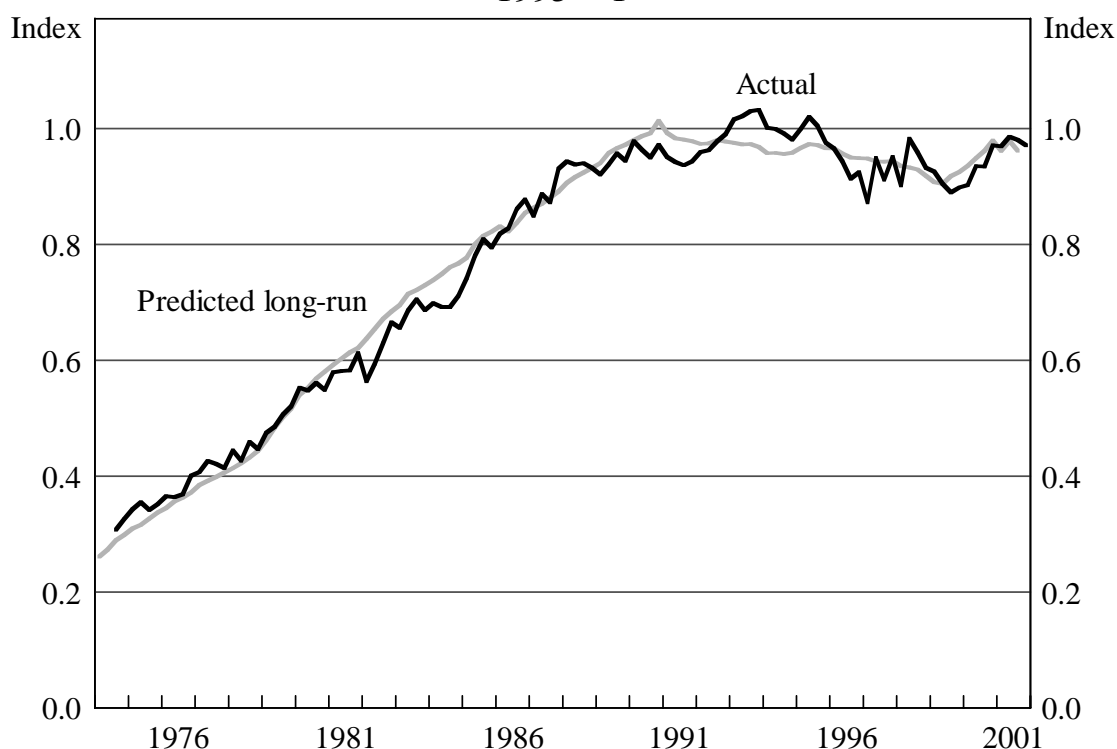
$$p_{man}^x = 0.2 + (1 - 0)(p_{ppi}) + 0(p_{cpi}^* - e^{twi}) - 0.01 t_{1986} \quad (8)$$

(0.03) (0.01) (0.001)

where p_{man}^x is the Australian price of manufactured exports. The results are illustrated in Figure 4.

Figure 4: Manufactured Export Prices

1995 = 1



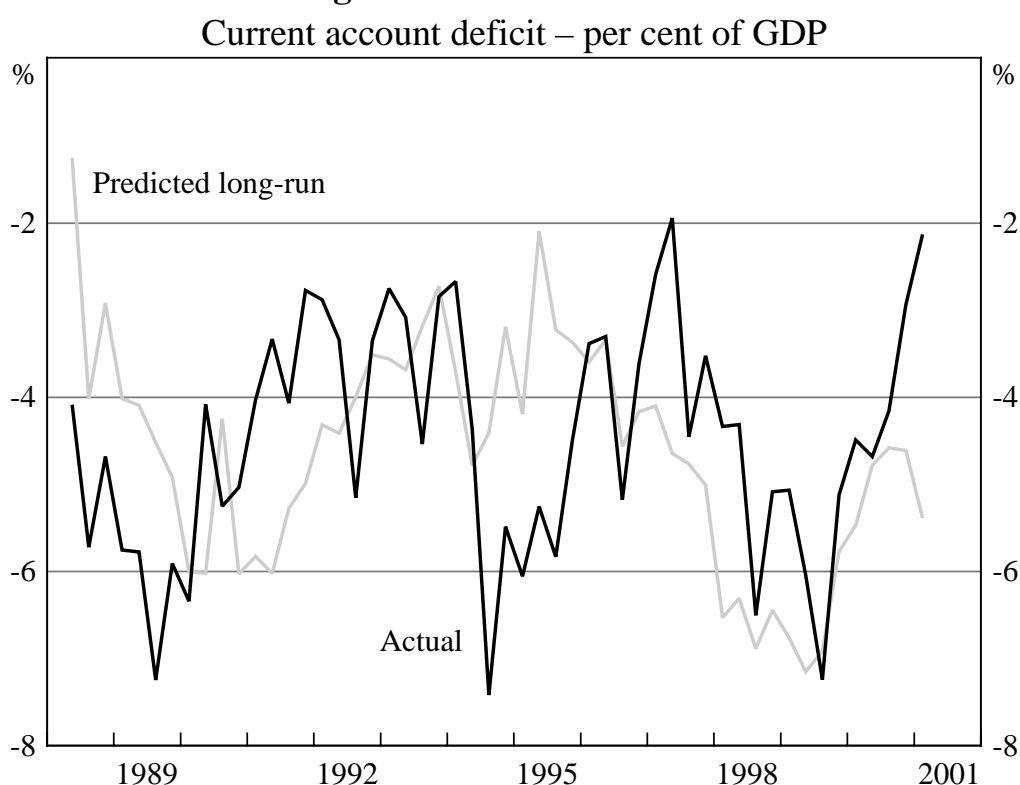
Appendix B gives the remaining trade equation estimates, plus the results for our model for income and transfers.

Overall, we are confident in our estimates of goods imports and service exports. This is not surprising since goods imports have been successfully modelled in other studies (e.g., Wilkinson (1992)). The equations for manufacturing, agriculture, and resource exports are econometrically sound, but the results are sensitive to changes in the specifications. The model for service imports, however, is less satisfactory, since we have to impose restrictions in order to obtain economically sensible results.

One of our aims is to estimate the exchange rate effect on the trade equations. We find a significant effect on the volumes of manufacturing and services exports, on the volumes of goods and services imports, and on the price of manufacturing exports. The assumption of price taking, which implies an exchange rate effect, is accepted for the prices of agriculture exports, resource exports, and goods imports. The exchange rate effect on service import prices, however, is imposed.

We can now add the different components of the current account. Figure 5 shows how the predicted values from our current account model compare against the actual values. We should bear in mind that our estimates are long-run estimates only, while the actual series also contains short-run dynamics, which will be poorly explained by our model. The model tracks the medium-run trends reasonably well in the early and late 1990s, but appears to be more problematic in the mid 1990s.

Figure 5: Current Account



Armed with the required elasticities, it is now possible to calculate the coefficients in Equation (3). In order to calculate the underlying current account for a specific period, we have to set the output gap to zero and we have to set the exogenous variables to their values in that period.¹⁰ The estimated underlying current account (and thus the estimated value for the equilibrium exchange rate) often changes considerably between different periods for a number of reasons. Firstly, it can be

¹⁰ The underlying current account is the sum of log-normally distributed variables, as the trade equations are estimated in log-linear form. We corrected for the transformation bias (of the mean) in the logarithmic regression using estimates of the covariance matrices as described in Section 3.4. In our case, the mean bias is very small – at around 1 per cent for the evaluation periods chosen.

the result of changes in exogenous variables. For example, world commodity prices, which are very volatile, appear to play an important role. Secondly, it can be the result of outliers. If, for example, the output gap is at extreme values, our model might give particularly inaccurate estimates. Finally, our current account model may have a poor fit over the specific period chosen. This can also affect the estimated equilibrium value.

3.3 Estimated Relationship between the Exchange Rate and the Current Account

We now have an equation for the underlying current account, as outlined in Step 2 of the procedure described in Section 2.2. Step 3 involves solving the underlying current account equation $KA = CA(E, Z)$ for the exchange rate, assuming different values of the target current account. This can be done algebraically once the exogenous variables Z have been set to their values in a specific reference period.

Table 2 summarises the results for the implied trade-weighted exchange rate index (TWI) equilibrium evaluated at some alternative reference points. Figure 6, which is the estimated equivalent to Figure 1 in Section 2.2, illustrates these results graphically. As predicted by theory, a larger current account deficit is consistent with an appreciation of the exchange rate. However, the estimated equilibrium exchange rate varies considerably over different reference periods, thus emphasising the uncertainty attached to any specific number.

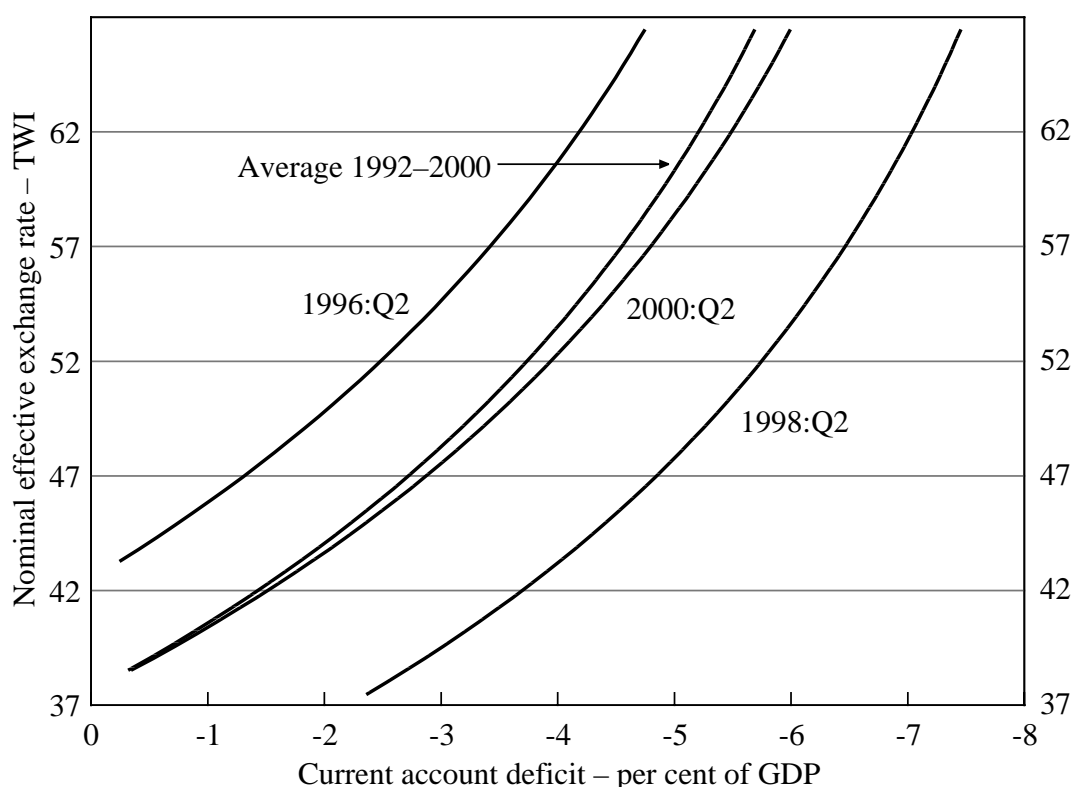
Table 2: Estimated Relationship between Effective Exchange Rate (TWI) and Current Account

Reference period	Ratio of current account to GDP Percentage points				
	-6	-5	-4	-3	-2
1996:Q2	79.5	68.8	60.7	54.6	49.8
1998:Q2	53.8	47.8	43.2	39.5	36.4
2000:Q2	66.5	58.4	52.3	47.5	43.6
1992–2000	70.0	60.3	53.5	48.3	44.1

Notes: Due to data constraints for the *NID* component denominated in foreign currency, we can evaluate the equilibrium exchange rate only up to 2000. The measure of the output gaps used for the specific reference periods is described in Appendix A. In calculating the figures in the 1992–2000 row, we assume an average output gap of zero over this period for both Australia and the world.

The variation of the underlying current account across different reference periods is due to changes in the exogenous variables which can affect the estimated exchange rate in two ways. First, the calculated equilibrium exchange rate is sensitive to the values of the exogenous variables in the reference period, especially if those values are outliers. Second, since those exogenous variables can change through time, the equilibrium exchange rate can also change through time.

Figure 6: Estimated Relationship between Effective Exchange Rate and Current Account



We can calculate the elasticity in the implied equilibrium exchange rate with respect to changes in exogenous parameters by evaluating the total differential of Equation (3). We concentrate on changes in output, foreign prices P^* ,¹¹ net foreign income NID and in the capital account.

$$d\left(\frac{KA}{PY}\right) = ca_E dE + ca_{p^*} dP^* + ca_y dY + ca_{y^*} dY^* + ca_D d\left(\frac{NID}{PY}\right) \quad (9)$$

¹¹ Since we have a number of different foreign prices, we set their rates of change equal for the purpose of this exercise.

where ca_z is the partial derivative of ca with respect to z . Solving the differential for the exchange rate shows how it must move to keep both sides of the current account identity equal to each other in response to changes in P^* , Y , Y^* , NID or KA .

The elasticities ca_z can be derived analytically from the estimated parameters of the current account components. In principle, they can be evaluated using any reference period. To illustrate, we evaluated all the partial derivatives in the second quarter of 2000 and obtained the empirical equivalent to Equation (9). We expressed some variables in percentage changes (in lower case and denoted by hats), and solved for the exchange rate:

$$\hat{e} = -4\hat{y} + 0.4\hat{y}^* - 10.6d\left(\frac{CA}{PY}\right) - 0.1d\left(\frac{NID}{PY}\right) + 1.9\hat{p}^* \quad (10)$$

The first and second terms on the right-hand side reflect the adjustment necessary to attain internal balance. Closing a negative domestic output gap of 1 percentage point of GDP for a given current account level is consistent with an estimated medium-term depreciation of the exchange rate by around 4 per cent. Without this depreciation, the stronger demand would take the current account away from the target level, due to the increased imports. Closing a 1 per cent foreign output gap would be consistent with an appreciation of the exchange rate by 0.4 per cent, which is about 10 times less than the effect of closing the domestic output gap. The coefficient on world GDP seems low, but it will be recalled that we are price takers for resource and agricultural exports. In these cases, changes in world demand effect exports mainly via their effects on export prices.

The most important coefficient in this equation is the semi-elasticity with respect to the current account to GDP ratio. Our model implies that an increase in the target capital account deficit of 1 percentage point of GDP would be consistent with about a 10 per cent appreciation of the equilibrium exchange rate in the medium term. Our value of 10 per cent is rather large compared with existing studies for other countries such as WD, who find elasticities around 5–7 per cent. However, this elasticity is the inverse of the elasticity of the current account with

respect to the exchange rate.¹² As noted by Goldstein and Khan (1985), estimated trade elasticities in the vicinity of zero are not uncommon. The viability of the macroeconomic balance approach depends upon this elasticity not being close to zero. In this case, implausibly large movements of the exchange rate may be needed to match the underlying current account with the assumed capital account value. As it is, this elasticity is 0.1, that is, a 1 per cent depreciation in the exchange rate raises the current account balance by 0.1 per cent of GDP.

Table 3 illustrates the results of Equation (10). It shows the estimated medium-term exchange rate elasticity with respect to changes in the output gap and the (target) capital account.

Table 3: Estimated Elasticities							
Percentage change in TWI							
Changes in KA_{target} Per cent of GDP	Closing domestic output gap Percentage points						
	1.5	1.0	0.5	0.0	-0.5	-1.0	-1.5
-2	-15	-17	-19	-21	-23	-25	-27
-1	-5	-7	-9	-11	-13	-15	-17
0	6	4	2	0	-2	-4	-6
1	17	15	13	11	9	7	5
2	27	25	23	21	19	17	15
				Internal balance			
							External balance

A current account deficit leads to continuing accumulation of foreign liabilities. The fourth term in Equation (10) demonstrates that the feedback effects of such accumulation onto the exchange rate are likely to be small. If net foreign liabilities grow at a faster rate than GDP, so that, for example, NID/GDP rises by 1 percentage point, the proportional change of the equilibrium exchange rate is -0.1 .

¹² This elasticity is sometimes related to the so-called Marshall-Lerner conditions for a depreciation to impact positively upon the current account. However, the Marshall-Lerner conditions have limited relevance for Australia. First, they are neither sufficient nor necessary if the current account starts from a position of deficit. Second, and more importantly, the conditions are only relevant where a country is a price setter for all of its exports.

The last term on the right-hand side is the independent effect of export prices on the equilibrium exchange rate. Since an increase in foreign export prices will boost export revenues, the exchange rate must appreciate in order to maintain the same current account. The coefficient on export prices seems high, compared with other studies that find a terms-of-trade elasticity of between 0.4 and 1.0 (Gruen and Wilkinson 1991; Blundell-Wignall *et al* 1993; Tarditi 1996). However, it is to be expected that changes to export prices may be associated with increases in domestic GDP. For example, a 10 per cent improvement of the terms of trade could be expected to increase domestic GDP by around 2 per cent.¹³ Based on Equation (10), this leads to an appreciation of approximately 10 per cent ($= 1.9 \cdot 10 - 4.1 \cdot 2$). Thus the full elasticity is approximately unity, sitting at one end of the range of the earlier studies.

3.4 Sensitivity Analysis

In Section 3.3 we have stressed the role of the exogenous variables as a source of uncertainty of our empirical results. However, like any estimated equation, our results are also subject to uncertainty arising from the use of econometric estimation techniques. Therefore, this section reports the results of a Monte-Carlo simulation of the confidence intervals around our estimates in Figure 6, evaluated in the second quarter of 2000. The confidence intervals are only indicative, since it is necessary to make a number of assumptions about the joint distributions of the estimated coefficients.

Our variable of interest – the estimated current account – is the sum of log-normally distributed variables (the trade equations are estimated in log-linear form) and normally distributed variables (*NID* and net transfer). Since we do not know the theoretical distribution of this sum, we use Monte-Carlo simulations to derive the confidence interval around the estimate of the current account.

The simulation consists of 5 000 random draws of the estimated coefficients, using the joint distributions from each estimated equation. We assume that the covariances between the components that we have estimated separately are zero.

¹³ Using the terms-of-trade adjusted GDP (Edey, Kerrison and Menzies 1987) $y_{tot} = y + tot \ x - x$. Since exports are roughly 20 per cent of GDP, a 10 per cent improvement in export prices is equivalent to a 2 per cent increase in y_{tot} .

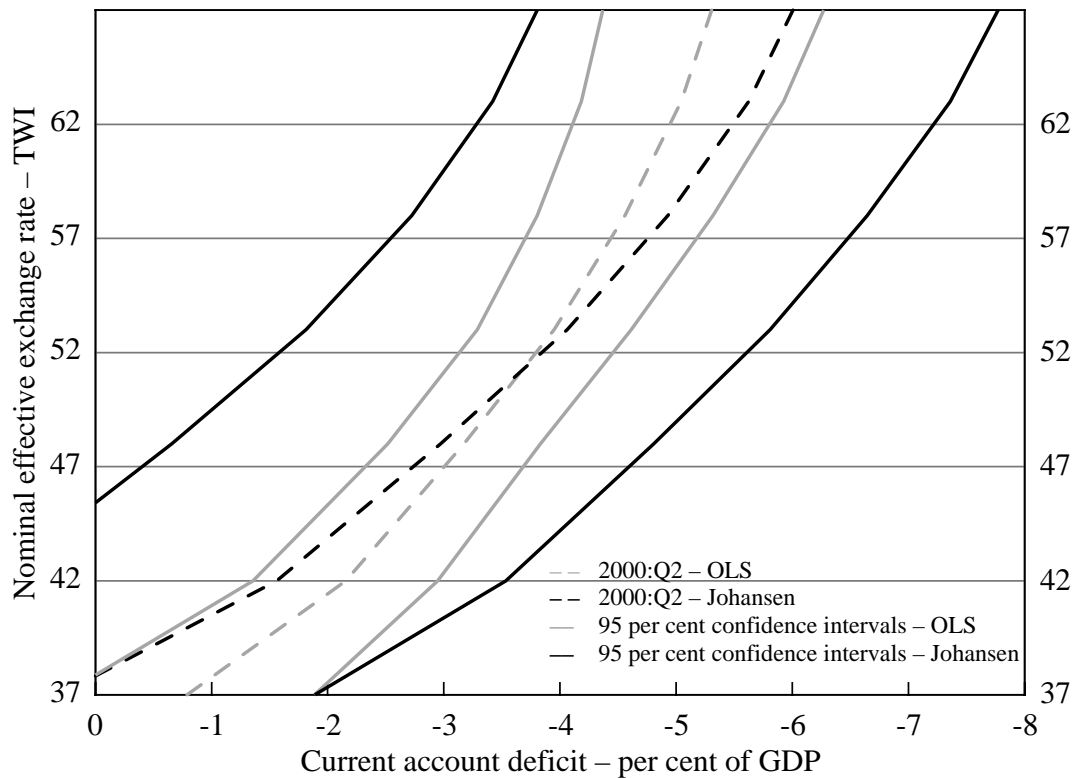
These random draws, combined with realisations of the variables for 2000:Q2, give 5 000 estimates of the underlying current account which we use to derive 95 per cent confidence intervals around the central estimate.

We have evaluated two benchmark cases. The first case uses the Johansen estimates from the results presented in Section 3.3. As the joint distribution of the constant with the other cointegrating parameter is not known, we had to calculate a value for the constant for each iteration.¹⁴ The second case uses OLS estimates for all equations.¹⁵ These have the advantage that the joint distribution of all coefficients of an individual equation is known.

Figure 7 shows the central estimates and the 95 per cent confidence intervals (solid lines) for both cases. The grey lines show the OLS estimates. As these estimates are numerically different from the Johansen estimates, the resulting exchange rate equation has a slightly different slope. The black lines show the estimates based on Johansen, with the central line equivalent to 2000:Q2 in Figure 6. The confidence intervals are wider than the OLS estimates, as the Johansen procedure involves the estimation of more parameters. In the case of the Johansen estimates, the confidence intervals encompass a range as wide as 20 index points on the TWI exchange rate.

¹⁴ The theoretical joint distribution of the long-run coefficients was taken from Johansen (1991). In the Johansen procedure, the constant in the cointegration space is calculated from $C_{LR} = \bar{Y} - \beta \cdot \bar{X}$ (where Y and X denote the cointegration variables and β is the vector of coefficients). As there is no theoretical expression for the covariance with the other cointegrating parameters, we did not draw a series for C_{LR} randomly. Instead, we calculated it using this formula for each draw of the other cointegration coefficients. In our case, the constant has a very large (sample) covariance with the cointegration coefficients on output, which impacts substantially on the width of our confidence intervals.

¹⁵ When estimating cointegrating vectors in I(1) systems, OLS is a super-consistent estimator but contains second-order biases. The Johansen estimator should in principle be preferred since it removes the bias in the median and the simultaneous equation bias (Banerjee *et al* 1993). This said, given our sample size, possible small sample problems of either estimator might be of more concern.

Figure 7: Confidence Intervals around the CA-Exchange Rate Relationship

4. Conclusion

In this paper, we have presented estimates of a model of exchange rate equilibrium consistent with internal and external balance. Internal balance is defined in terms of output being at potential; external balance is reached when the current account (and therefore also the capital account) is at some target value.

We remain agnostic in the paper about the appropriate sustainable target value for the current account. Our aim, instead, is to estimate the level of the exchange rate consistent with alternative possible values for the target current account. Not surprisingly, the model has the property that lower values of the assumed medium-term current account deficit are associated with a lower medium-term exchange rate. However, the estimates of this relationship are highly sensitive to the choice of estimation period and to the values of key export and import elasticities.

Appendix A: Data

This appendix provides a glossary of all the variables with details of the data sources. The data is sourced from the Australian Bureau of Statistics (ABS), the IMF's *International Financial Statistics* (IFS), the OECD, the Reserve Bank of Australia (RBA), and our own calculations.

The base year for all price and volume indices is 1995. The dates in brackets indicate the timespan of the individual series. Unless otherwise stated all variables are seasonally adjusted. World prices/quantities are marked with an asterisk (*). Lower-case variables are logs of the corresponding upper-case variables.

A_t **Foreign assets**

Definition: Foreign assets in A\$, converted into real terms using P_{gdp}

Source: ABS Cat No 5302.0 (1994:Q1–2001:Q4)

CA_t **Current account**

Definition: Current account, converted into A\$ using e^{us}

Source: IFS line AUI78ALDA (1960:Q1–2001:Q1)

D_t **Foreign liabilities**

Definition: Foreign liabilities in A\$, converted into real terms using P_{gdp}

Source: ABS Cat No 5302.0 (1991:Q3–2001:Q4)

e_t^{twi} **Trade-weighted exchange rate**

Definition: Trade-weighted exchange rate index for the A\$

Source: RBA (1988:Q1–2002:Q3); own calculations using geometric weights (see also Ellis (2001)) (1970:Q2–1987:Q4)

e_t^{US} **Nominal bilateral exchange rate (US\$)**

Definition: Nominal bilateral exchange rate, A\$ units per US\$

Source: IFS line AUI..AF (1960:Q1–2001:Q4)

$M_{t,gds}$ **Import volume (goods)**

Definition: Volume of goods imports

Source: Calculated using $M_{gds}^m = V_{gds}^m / P_{gds}^m$ (1960:Q1–2001:Q4)

$M_{t,srv}$ **Import volume (services)**

Definition: Volume of service imports

Source: Calculated using $M_{srv}^m = V_{srv}^m / P_{srv}^m$ (1984:Q3–2001:Q4)

NT_t **Net transfers**

Definition: Real net transfers, converted into A\$

Source: IFS line AUI78AJDA minus AUI78AKDA, converted into A\$ using e_t^{us} and into real terms using P_{gdp} (1960:Q1–2001:Q1)

$P_{t,gds}^m$ **Import price (goods)**

Definition: Implicit price deflator of goods imports

Source: ABS Cat No 5302.0 (1960:Q1–2002:Q1)

$P_{t,srv}^m$ Import price (services)

Definition: Implicit price deflator of service imports

Source: ABS Cat No 5302.0 (1984:Q3–2001:Q4)

 $P_{t,agr}^x$ Export price (agriculture)

Definition: Implicit price deflator of agricultural exports

Source: Calculation using V_{agr}^x deflated by a chain volume measure of rural exports (ABS Cat No 5302.0) (1974:Q3–2001:Q4)

 $P_{t,man}^x$ Export price (manufacturing)

Definition: Implicit price deflator of manufactured exports

Source: Calculation using V_{man}^x deflated by a chain volume measure of manufactured exports (ABS Cat No 5302.0) (1974:Q3–2001:Q4)

 $P_{t,res}^x$ Export price (resources)

Definition: Implicit price deflator of resource exports

Source: Calculation using V_{res}^x deflated by a chain volume measure of resource exports (ABS Cat No 5302.0) (1974:Q3–2001:Q4)

 $P_{t,srv}^x$ Export price (services)

Definition: Implicit price deflator of service exports

Source: ABS Cat No 5302.0 (1984:Q3–2002:Q1)

$P_{t,cpi}$ Consumer price index

Definition: Australian consumer price index

Source: IFS line AUI64...F (1960:Q1–2001:Q3)

 $P_{t,gdp}$ GDP deflator

Definition: Australian GDP deflator

Source: ABS Cat No 5206.0 (1960:Q1–2002:Q1)

 $P_{t,lab}$ Real unit labour costs

Definition: Real unit labour costs

Source: Calculation using $P_{lab} = P_{ulc} / P_{gdp}$ (1975:Q1–2001:Q3)

 $P_{t,ppi}$ Producer prices

Definition: Price index of manufactured goods (articles produced)

Source: RBA, unpublished (1968:Q3–2001:Q4)

 $P_{t,ulc}$ Nominal unit labour costs

Definition: Nominal unit labour costs

Source: Calculation using total wage divided by productivity, where productivity is GDP divided by the average hours worked (1975:Q1–2001:Q4)

$P_{t,gds}^{*,x}$ **World export prices**

Definition: Trade-weighted world export price index

Source: Own calculation using the TWI weights and the export price series for each country from Datastream (1970:Q2–2002:Q2)

$P_{t,cpi}^*$ **World consumer prices**

Definition: World consumer price index

Source: IFS line WDI64...F (1968:Q1–2001:Q3)

$P_{t,oil}^*$ **World oil price**

Definition: World spot price of petroleum, index

Source: IFS line WDI76AAZA in US\$ per barrel, converted into an index (1960:Q1–2001:Q4)

$P_{t,food}^*$ **World food price**

Definition: World food price index in US\$

Source: IFS line WDI76EXDF (1960:Q1–2001:Q4)

$P_{t,mm}^*$ **World base metals prices**

Definition: World base metals price index in US\$

Source: IFS line WDI76AYDF (1960:Q1–2001:Q4)

$P_{t,coal}^*$ **World coal price**

Definition: World price of coal, index

Source: IFS line AUI74VRDF in US\$ per metric ton, converted into an index (1966:Q3–2002:Q1)

$P_{t,res}^*$ **World price of resources**

Definition: World price of resources

Source: Calculation using $P_{res}^* = 0.37P_{nm}^* + 0.22P_{coal}^* + 0.15P_{oil}^*$. The weights are value weights for each subcategory as at March 2002 (1966:Q3–2001:Q4)

r_t^A **Rate of return of foreign assets**

Definition: Implied return on foreign assets

Source: Calculation using income credits (IFS line AUI78AGDA), converted into A\$ using e^{us} and into real terms using P_{gdp} . The implied rate is then calculated from quarterly estimates of A (1994:Q1–2001:Q1)

r_t^D **Rate of return of foreign liabilities**

Definition: Implied return on foreign liabilities

Source: Calculation using income debits (IFS line AUI78AHDA), converted into A\$ using e^{us} and into real terms using P_{gdp} . The implied rate is then calculated from quarterly estimates of D (1991:Q3–2001:Q1)

$S_{t,agr}$ Agricultural subsidies

Definition: Agricultural subsidies

Source: ABS Cat No 5206.0 in A\$, converted into real terms using P_{gdp} (1977:Q4–2001:Q4)

 $V_{t,gds}^m$ Import value (goods)

Definition: Value of goods imports, not seasonally adjusted

Source: ABS Cat No 5302.0 in A\$ (1960:Q1–2001:Q4)

 $V_{t,svr}^m$ Import value (services)

Definition: Volume of service imports, not seasonally adjusted

Source: ABS Cat No 5368.0 in A\$ (1960:Q1–2001:Q4)

 $V_{t,agr}^x$ Export value (agriculture)

Definition: Value of agricultural exports

Source: ABS Cat No 5302.0 in A\$ (1969:Q3–2001:Q4)

 $V_{t,man}^x$ Export value (manufacturing)

Definition: Value of manufactured exports

Source: ABS Cat No 5302.0 in A\$ (1969:Q3–2001:Q4)

$V_{t,res}^x$ Export value (resources)

Definition: Value of resource exports

Source: ABS Cat No 5302.0 in A\$ (1960:Q1–2001:Q4)

 $V_{t,sv}^x$ Export value (services)

Definition: Value of service exports, not seasonally adjusted

Source: ABS Cat No 5368.0 in A\$ (1960:Q1–2001:Q4)

 $V_{t,y}$ Australian nominal GDP

Definition: Australian nominal GDP

Source: ABS Cat No 5206.0 in A\$ (1960:Q1–2002:Q1)

 $X_{t,agr}^x$ Export volume (agriculture)

Definition: Volume of agricultural exports

Source: Calculation using $X_{agr}^x = V_{agr}^x / P_{agr}^x$ (1974:Q3–2001:Q4)

 $X_{t,man}^x$ Export volume (manufacturing)

Definition: Volume of manufactured exports

Source: Calculation using $X_{man}^x = V_{man}^x / P_{man}^x$ (1974:Q3–2001:Q4)

 $X_{t,res}^x$ Export volume (resources)

Definition: Volume of resource exports

Source: Calculation using $X_{res}^x = V_{res}^x / P_{res}^x$ (1974:Q3–2001:Q4)

$X_{t,svr}^x$ **Export volume (services)**

Definition: Volume of service exports

Source: Calculation using $X_{svr}^x = V_{svr}^x / P_{svr}^x$ (1984:Q3–2001:Q4)

Y_t **Australian real GDP**

Definition: Australian real GDP

Source: Calculation using $Y = V_y / P_{gdp}$ (1960:Q1–2002:Q1)

The estimate of the domestic output gap in the reference periods for Table 2 and Figure 6 was taken from Gruen, Robinson and Stone (2002). We modified their output gap measure in order to obtain a cyclical measure which is ‘at trend’ when actual inflation is constant. For this, we adjusted the final output gap estimate in their Table 2 by setting the bond market inflation expectations to zero. We did this by calculating $gap_t^{New} = \frac{\beta_1}{\gamma} bond_{t-1} + gap_t^{GRS}$.

Y_t^* **World real GDP**

Definition: OECD real GDP

Source: OECD, QNA line OC001000D (annual) in US\$ at 1995 prices and PPP exchange rates, converted into quarterly numbers (1960:Q1–2001:Q3)

The estimate of the world output gap in the reference periods for Table 2 and Figure 6 was taken from OECD (2002).

Appendix B: Estimation Results

In this appendix we describe the estimated equations of the current account components. All lower-case variables are in logs. For illustration purposes we only report the long-run coefficients of the VECM estimates. The estimated equations show the point estimates with the standard errors (where available) in brackets.

Agricultural Exports

This is described in the main text.

Resource Exports

We assume that Australian producers of resources are price takers, therefore we are left with estimating the supply curve. Resource export supply is a function of real unit labour costs and the level of real GDP, which capture capacity constraints and factor costs. A significant price effect with the correct sign could not be detected.

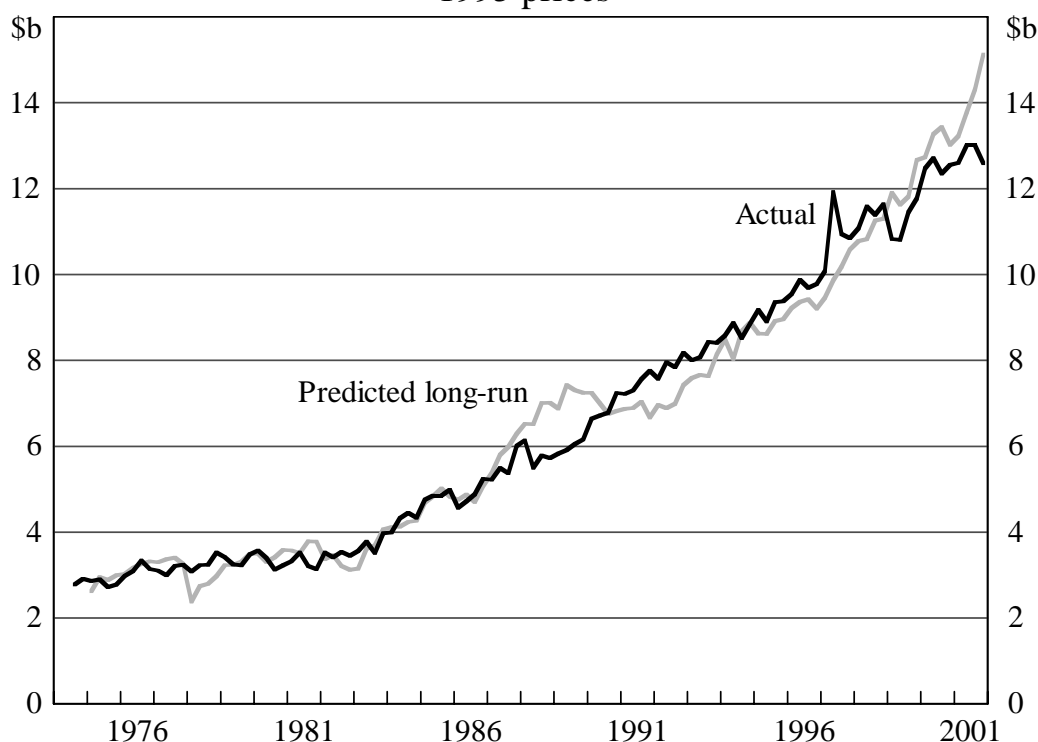
We estimate the long-run relationship below using a VECM with eight lags. Figure B1 shows how our long-run model compares with the actual series.

$$x_{res} = -11.7 - 2.5 p_{lab} + 1.8 y \quad (\text{B1})$$

(0.7) (0.1)

where x_{res} is the volume of resource exports, p_{lab} are real unit labour costs, and y is Australian real GDP.

Figure B1: Resource Export Volumes
1995 prices



Manufactured Exports

This is described in the main text.

Service Exports

For service exports we assume Australian producers are price setters. This allows us to concentrate on estimating the demand curve only. Demand for service exports is modelled as a function of relative prices and world income.

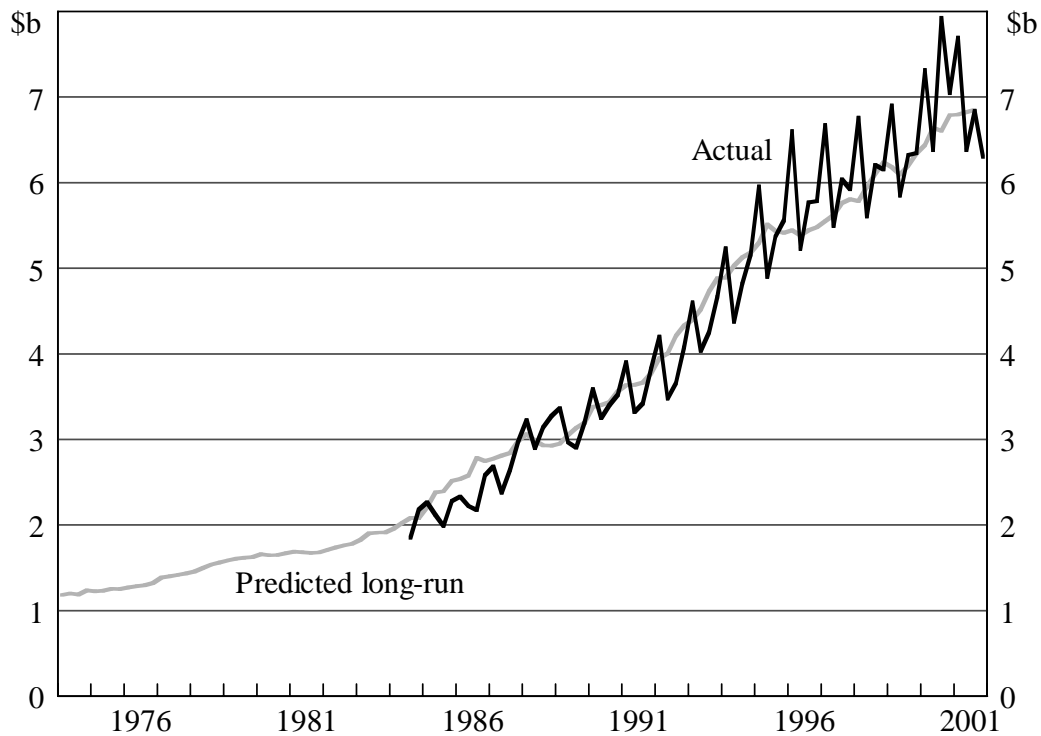
We estimate the long-run relationship below using a VECM with eight lags.

$$x_{srv} = -3.9 + 0.5(p_{cpi}^* - e^{twi} - p_{cpi}) + 0.8y^{world} \quad (\text{B2})$$

(0.04) (0.2)

where x_{srv} is the volume of exported services, p_{cpi}^* is the world CPI, e^{twi} is the effective exchange rate, p_{cpi} is Australian CPI, and y^{world} is world real GDP. The result is illustrated in Figure B2.

Figure B2: Service Export Volumes
1995 prices



The price setting assumption is worth an additional comment. We assume that the Australian price of service exports is determined by the Australian CPI. However, a level shift is apparent from 1994 in the service exports price deflator (see Figure B3), caused by a drop in the price deflator of two of the five subcategories of service exports. The change in the way these series are measured is responsible for the sudden level shift.¹⁶ We include in our model of export service prices a dummy variable to capture this change. Note that the regression is in levels, rather than logs.

¹⁶ From December quarter 1994, these two subcategories ('transportation services' and 'passenger and other services') are linked to the CPI for international airfares whereas prior to that quarter they are calculated as the total revenue earned from abroad and home divided by the number of arrivals and departures (personal communication with the ABS).

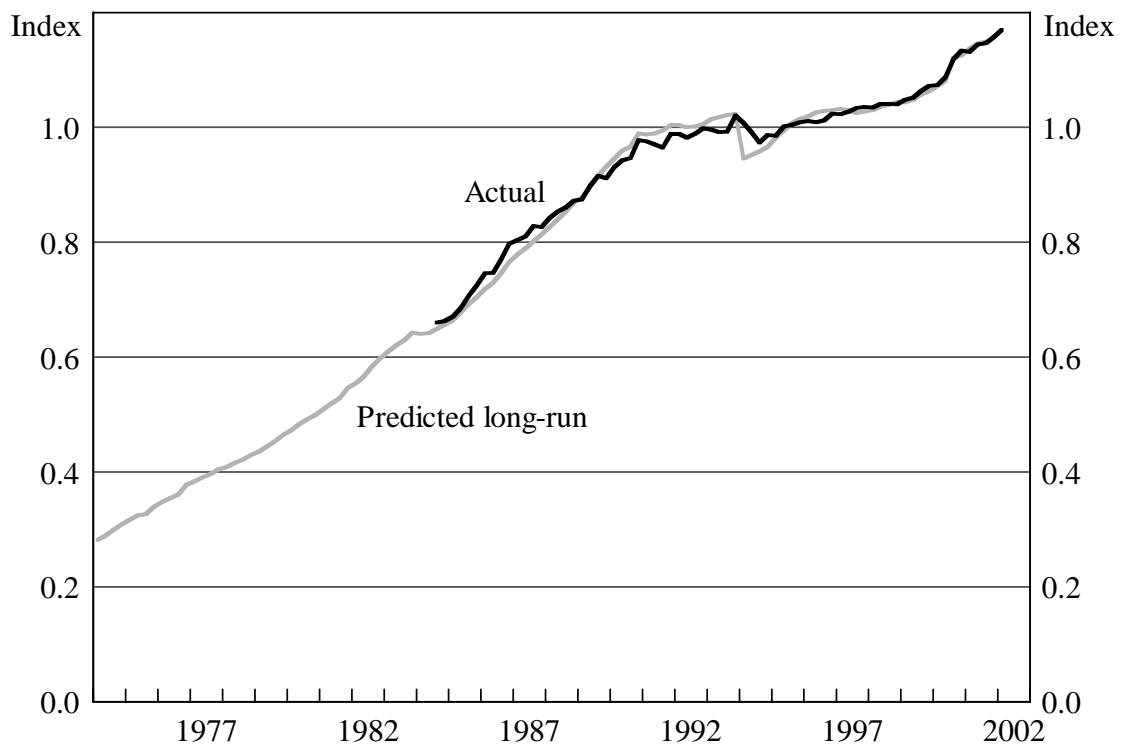
$$P_{srv}^x = 0.1D1 + P_{cpi} \quad (B3)$$

(0.003)

where P_{srv}^x is the Australian price of exported services, P_{cpi} are Australian consumer prices, $D1 = 1$ in all time periods before 1994:Q1, and $D1 = 0$ in all time periods including and following 1994:Q1.

Initially we estimated this equation using unrestricted OLS and used these results to test the hypothesis that the coefficient on P_{cpi} was unity, which was accepted (p -value in excess of 0.55). This confirms that our assumption of price setting is reasonable. We therefore imposed this restriction for the estimation results presented in Equation (B3).

Figure B3: Service Export Prices
1995 = 1



Service Imports

It proved to be very difficult to find a model of service imports. Estimates were highly dependent upon the technique and the dynamic structure chosen. The impact of the exchange rate was difficult to gauge. It appeared to have a significant impact on volumes but with the wrong sign. For prices, there was very low pass-through of exchange rate changes. We obtained exchange rate elasticities by combining regression analysis (with economic priors imposed) and personal communication with the ABS.¹⁸

For volumes (Figure B5), we imposed a zero exchange rate effect, and estimated a long-run relationship using a VECM with three lags.

$$m_{srv} = -4.6 + 1.1y \quad (B5)$$

(0.1)

where m_{srv} is the volume of imported services and y is Australian GDP.

For prices, we explain the Australian dollar price of imported services as a function of the world CPI and the exchange rate, using the following equation.

$$p_{srv}^m = 0.03 + 0.5(p_{cpi}^* - e^{twi}) \quad (B6)$$

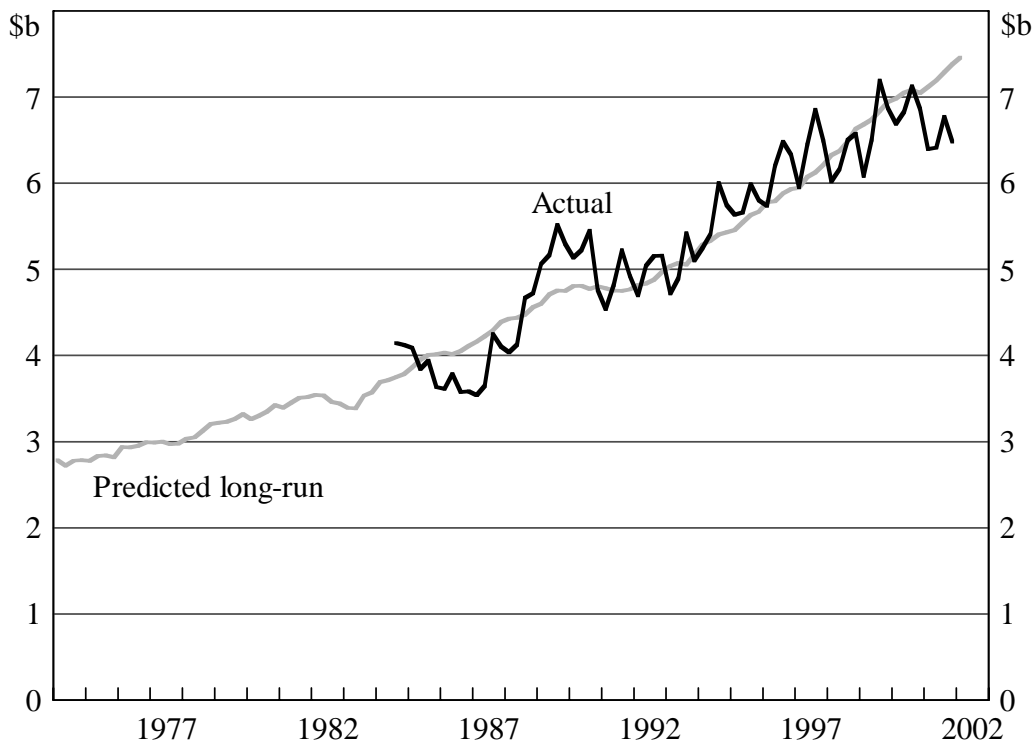
(0.01)

where p_{srv}^m is the Australian price of imported services, p_{cpi}^* are world consumer prices, and e^{twi} is the effective exchange rate.

¹⁸ Ideally, one would estimate a reduced form as in the case of manufactured exports. However, the estimated coefficients in such a model are not theoretically consistent (the income and price elasticities both have the wrong sign), whereas the model we use gives theoretically consistent results.

Initial estimates of this equation gave a pass-through well below unity (0.2). Upon consultation with the ABS, we decided to impose an exchange rate elasticity of 0.5.¹⁹ In our preferred model, we imposed the elasticity and used OLS to estimate the constant. This model predicts quite well from the mid 1990s as can be seen in Figure B6.

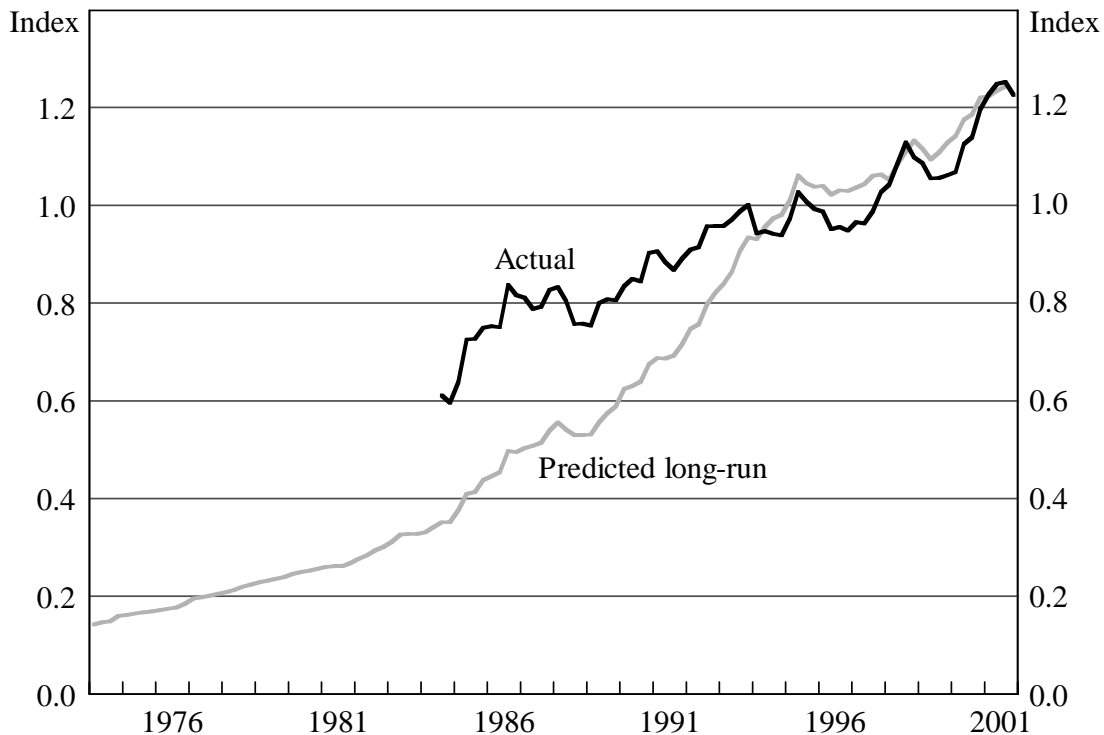
Figure B5: Service Import Volumes
1995 prices



¹⁹ In a typical year, service imports are split evenly three ways between transport (half being sea freight and half being passenger air travel), travel (service imports for tourists, such as haircuts) and other services (business services, royalties, communications, accounting services, embassy expenditures etc). With regard to the exchange rate effect on transport prices, significant oversupply exists in container shipping and passenger air travel, so it may be the case that carriers are pricing to market. However, one would expect much of the travel is priced in overseas currency, as is a sizable proportion of other services (personal communication with the ABS). As a rough guess, we decided that about half of service imports could have full exchange rate pass-through.

Figure B6: Service Import Prices

1995 = 1

**Net Income Deficit (NID)**

The net income deficit is the difference between income credits (payments accruing to foreign assets) and income debits (payments accruing to foreign liabilities).²⁰ Since we only incorporate the valuation effects arising from changes in the exchange rate, income credits and debits need not be estimated. Here all variables are in levels.

$$\text{Income credits} = \left(a_1 \frac{A}{e^{twi}} + (1 - a_1)A \right) r^A \quad (\text{B7})$$

where α_1 denotes the proportion of foreign assets denominated in foreign currency (in our case US\$), A is the stock of foreign assets (equity + debt) in Australian dollars, e^{twi} is the effective exchange rate, and r^A is the implied interest rate on foreign assets.

²⁰ Compensation from foreign employment is a third component. However, this is negligible in size, and we have therefore excluded it from our analysis.

$$\text{Income debits} = \left(a_2 \frac{D}{e^{twi}} + (1 - a_2)D \right) r^D \quad (\text{B8})$$

where α_2 denotes the proportion of foreign liabilities denominated in foreign currency, D is the stock of foreign liabilities (equity + debt) in Australian dollars, e^{twi} is the effective exchange rate, and r^D is the implied interest rate on foreign liabilities.

The share of assets and liabilities denominated in US\$ is the actual share in the reference period, for which the equilibrium exchange rate is evaluated. For the June quarter 2000, we calculate that $\alpha_1 = 0.91$ and $\alpha_2 = 0.36$.²¹ That implies that while most foreign assets are denominated in foreign currency, most foreign liabilities are denominated in Australian dollars. Although net foreign liabilities are positive, and equal to roughly 60 per cent of GDP, net foreign liabilities *denominated in foreign currency* are actually (slightly) negative. This has the surprising implication that a depreciation fails to increase net income outflows.²²

Transfers

Net transfers are modelled using a simple linear time trend. All variables are levels. The coefficients are estimated using OLS.

$$NT = -221.2 + 1.2t \quad (\text{B9})$$

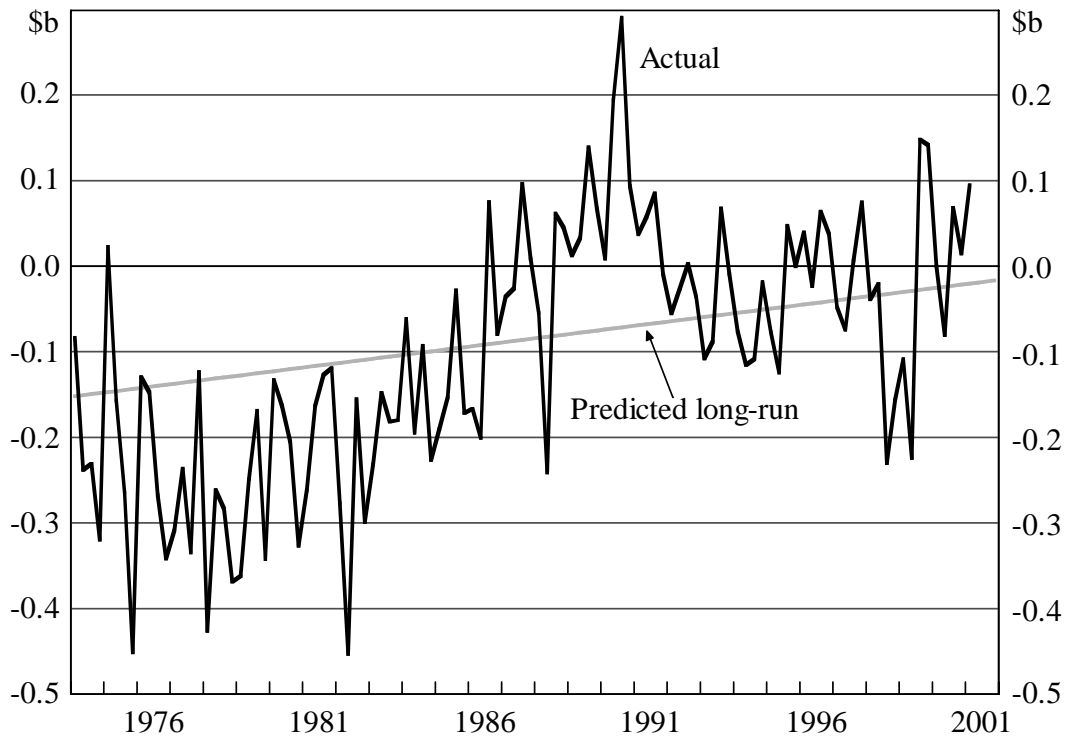
(17.9) (0.2)

where NT are net transfers (in Australian dollars) and t is a time trend. The estimated trendline is show in Figure B7.

²¹ We use an internal data source which corresponds to that in ABS Cat No 5352.0. These data are subject to frequent revisions. The figures are current as at June 2002.

²² Not surprisingly, both income credits and income debits fitted the data well, since the model has the US\$ levels of each available in the simulation.

Figure B7: Net Transfers
Volumes



Appendix C: Time Series Properties and Model Selection

Unit Root Tests

We tested for the presence of a unit root in all series. Both the augmented Dickey-Fuller test (ADF) and the Phillips-Perron (PP) tests suggest that all the data are I(1) with one exception. We can reject empirically that world output has a unit root over our sample period. However, we assume that the series is I(1) *a priori* on economic grounds.

Table C1: Results of ADF and PP Tests

Variable	ADF on levels	ADF on 1 st differences	Conclusion (5 per cent level)	PP on levels	PP on 1 st differences	Conclusion (5 per cent level)
x_{agr}	-0.7	-5.7***	I(1)	-1.70	-11***	I(1)
x_{res}	0.2	-4.9***	I(1)	-0.02	-15***	I(1)
x_{man}	0.8	-4.8***	I(1)	1.00	-14***	I(1)
x_{srv}	-1.9	-2.7*	I(1)	-2.10	-22***	I(1)
m_{gds}	0.1	-7***	I(1)	-0.10	-11***	I(1)
m_{srv}	-1.5	-2.8*	I(1)	-0.90	-9***	I(1)
s_{agr}	-1.2	-5.6***	I(1)	-3.00**	-14***	I(0)
p_{lab}	-1.9	-5.7***	I(1)	-2.70*	-13***	I(1)
$p_{cpi}^*/(e^{twi} p_{ppi})$	0.4	-3.4**	I(1)	0.70	-9***	I(1)
$p_{cpi}^*/(e^{twi} p_{cpi})$	0.4	-3.4**	I(1)	0.80	-9.5***	I(1)
$p_{gds}^{*x}/(e^{twi} p_{ppi})$	-1.0	-4.8***	I(1)	-1.40	-11***	I(1)
y	-1.5	-6***	I(1)	-1.30	-14***	I(1)
y^*	-3.3**	-4.6***	I(0)	-3.90***	-7***	I(0)

Notes: *, ** and *** indicates significance at the 10, 5 and 1 per cent levels. All test specifications include an intercept but no trend.

Model Selection

As our data are I(1) we have to test for cointegration between the volume components and possible explanatory variables. Our chosen procedure is the one suggested by Johansen (1991, 1995). However, this procedure may fail to detect genuine cointegration for small sample sizes. We therefore tested whether the deviations from the Johansen long-run relationships were stationary using ADF

and PP tests. We also tested whether the residuals from each equation in the VECM are white noise. Finally, we compared our results from the VECM estimation with ECM and OLS estimates to ensure the signs and magnitudes were similar.

The number of cointegrating equations

Assuming that we are satisfied that all of the relevant variables are $I(1)$, then we require that there be some cointegrating vector that will combine them in such a way as to make them stationary. If we fail to find a cointegrating relationship, there is little we can do in modelling these variables. Hence, our choice of lag length and explanatory variables was partly driven by the need to find a cointegrating vector, rather than traditional model selection criteria such as the AIC or BIC.

Moreover, it is unclear how to treat a relationship where there may exist more than one cointegrating vector. This consideration also influenced our choice of lag length and explanatory variables. We present the results of the Johansen procedure for various lag lengths in Table C2.

Before we apply the Johansen procedure we have to make some assumptions regarding the deterministic trends in the VAR. A general form of the VECM is given below.

$$\Delta y_t = (\alpha\beta' y_{t-1} + \alpha\mu_1 i + \alpha\delta_1 t) + \sum \Gamma_i \Delta y_{t-i} + \mu_2 i + \delta_2 t + \varepsilon_t \quad (C1)$$

where y is a vector of endogenous variables, i is a vector of ones, t is a time trend, and $\Pi = \alpha\beta'$. The terms in brackets represent the long-run relationship or cointegration space. In this general specification it is possible to have a constant and/or a time trend in both cointegration space and in the error correction system. For our purposes we assume that $\delta_1 = \delta_2 = 0$. That is, we allow only for a constant but no time trend. Because the dependent variables are expressed in differences, using a time trend implies that this variable changes at an increasing rate with time, that is, a quadratic trend. On economic grounds, we find it difficult to justify using a quadratic trend to model our variables.

We use the Trace test proposed by Johansen (1995) to test for the number of non-zero characteristic roots of Π (which is equivalent to the number of cointegrating relationships). For the hypothesis that there are at most r distinct cointegrating vectors, the Trace test statistic is given by:

$$TR = T \sum_{i=r+1}^N \ln(1 - \hat{\lambda}_i) \quad (C2)$$

where $\hat{\lambda}_i$ are the eigenvalues of Π sorted from highest to lowest. The critical values used in these tests are those from Osterwald-Lenum (1992).

Table C2: Results of the Johansen Procedure

	Lags										
	2	3	4	5	6	7	8	9	10	11	12
	Number of cointegrating vectors										
Exports											
Agricultural	1	1	1	1	1	1	1	1	2	2	2
Resource	0	0	0	0	0	0	1	0	2	0	0
Manufactured	1	1	0	0	0	0	1	3	3	3	3
Services	1	1	0	1	1	1	1	1	2	2	2
Imports											
Goods	1	1	1	1	1	1	1	1	1	1	1
Services	0	0	0	0	0	0	1	0	0	1	1

Note: Using 10 per cent level of significance and critical values from Osterwald-Lenum (1992).

Robustness to lag length

While our choice of lag length was influenced by the results of the Johansen procedure, we took great care not to impose a lag structure to which our point estimates were not robust. It may have been the case that we chose a lag structure because it allowed for a single cointegrating vector over a lag structure that was preferred on the basis of the AIC and BIC. However, in these cases we checked that the point estimates under our chosen lag structure were robust to this lag structure. The results of these tests are presented in Table C3.

Table C3: Sensitivity of Point Estimates to Lag Length

	Lags						
	2	3	4	5	6	7	8
Exports							
Agricultural							
s_{agr}	-0.2 (-4.6)	-0.2 (-4.5)	-0.2 (-4.8)	-0.2 (-5.3)	-0.2 (-6.2)	-0.2 (-6.3)	-0.2 (-9.4)
Y	1.7 (9.8)	1.6 (10.6)	1.7 (10.2)	1.6 (12)	1.8 (12.5)	1.8 (12.6)	1.8 (18.3)
Resource							
p_{lab}	-4.4 (-2.2)	-5.0 (-2.1)	-5.6 (-1.8)	0.7 (0.6)	3.5 (1)	35 (0.2)	-2.5 (-3.6)
Y	1.6 (6.8)	1.5 (5.6)	1.4 (3.9)	2.1 (13.3)	2.4 (6.1)	5.9 (0.4)	1.8 (20.7)
Manufactured							
$p_{cpi}^* / (e^{twi} p_{ppi})$	1 (6.1)	0.8 (7.7)	0.9 (5.9)	0.9 (5.8)	0.9 (5.8)	0.7 (6.6)	0.8 (7.5)
$T2$	0.002 (0.3)	0.007 (2.1)	0.004 (0.7)	0.003 (0.5)	0.004 (0.8)	0.01 (3)	0.006 (1.7)
Services							
$p_{cpi}^* / (e^{twi} p_{cpi})$	0.4 (8.5)	0.5 (8.7)	0.5 (7.8)	0.5 (7.4)	0.5 (12.1)	0.5 (13.6)	0.5 (11.3)
y^*	1.2 (5.5)	0.9 (3.5)	0.9 (3.2)	0.6 (1.6)	0.7 (3.2)	0.6 (3.3)	0.8 (4.1)
Imports							
Goods							
$p_{gds}^* / (e^{twi} p_{ppi})$	-0.6 (-6.2)	-0.7 (-6.2)	-0.7 (-7.9)	-0.7 (-11.3)	-0.7 (-10.5)	-0.7 (-13.4)	-0.8 (-13.7)
Y	1.8 (49.8)	1.8 (49.5)	1.8 (60.8)	1.8 (80.4)	1.8 (73.7)	1.8 (93.7)	1.8 (90.4)
Services							
Y	1.2 (9.9)	1.1 (8.3)	1.2 (9.9)	0.9 (4.6)	1 (7.8)	1 (5.2)	0.2 (0.2)

Notes: Numbers in bold are the point estimates. Numbers in brackets are t -statistics for the test that the point estimate is zero.

Are deviations from the estimated long-run stationary?

In one particular case (service import volumes) we found no evidence of a cointegrating vector using the Johansen methodology. However, when we combined the variables according to the ‘candidate cointegrating vector’ (i.e., eigenvector corresponding to the largest eigenvalue), we found the deviations from the long-run relationship to be stationary. This, in spite of the fact that the ADF and PP tests have low power and thus have difficulty in rejecting the null of a unit root in favour of stationarity. In this case we went against the results of the Johansen procedure and imposed the ‘candidate cointegrating vector’ as a cointegrating relationship. A possible justification is that the sample size in this particular case may have been too low for the Johansen procedure to give reliable results.

In general, we tested whether each of our cointegrating relationships gave stationary deviations from the long run they implied. The results are presented in Table C4.

Table C4: Results of Tests for Stationary Deviations from the Long Run

	Lags	ACF test statistic	PP test statistic
Exports			
Agricultural	4	-3.7***	-4.7***
Resource	8	-1.8*	-2.6***
Manufactured	8	-1.9	-2.8*
Services	8	-2.5**	-8.7***
Imports			
Goods	4	-6.2***	-6.8***
Services	3	-0.8	-3.1***

Notes: The ADF and PP tests on manufactures include an intercept because we were able to reject a mean of zero for the deviations from the long-run in this case. For all the other equations the ADF and PP tests have no intercept. *, ** and *** indicates that we can reject the null hypothesis at the 10, 5 and 1 per cent significance level.

Are the VECM residuals white noise?

Another consideration when choosing our lag structure was to ensure that the residuals from each equation in the VECM were white noise. We tried to choose a lag structure that satisfied this requirement. In order to test this we visually

inspected the ACF and PACF of each residual series. The results of these tests are presented in Table C5.

Table C5: Results of Tests on VECM Residuals														
	Lags													
	ACF							PACF						
	2	3	4	5	6	7	8	2	3	4	5	6	7	8
Exports														
Agricultural														
x_{agr}	F	F	P	P	P	P	P	F	F	P	P	P	P	P
s_{agr}	P	F	F	F	F	F	F	P	F	F	F	F	F	F
y	P	P	P	P	F	F	F	P	P	P	P	F	F	F
Resource														
x_{res}	F	P	P	P	P	P	P	F	P	P	P	P	P	P
p_{lab}	P	P	P	P	P	P	P	P	P	P	P	P	P	P
y	P	P	P	P	P	P	P	P	P	P	P	P	P	P
Manufactured														
x_{man}	F	F	F	F	F	F	P	F	F	F	F	F	F	P
$p_{cpi}^* / (e^{twi} p_{ppi})$	F	P	P	P	P	P	P	F	P	P	P	P	P	P
$T2$	P	P	P	P	P	P	P	P	P	P	P	P	P	P
Services														
x_{srv}	P	P	P	P	P	P	P	P	P	P	P	P	P	P
$p_{cpi}^* / (e^{twi} p_{cpi})$	P	P	P	F	P	P	P	P	P	P	F	P	P	P
y^*	P	P	P	P	P	F	P	P	P	P	P	P	F	P
Imports														
Goods														
m_{gds}	F	P	P	P	P	P	F	F	F	P	P	P	P	F
$p_{gds}^* / (e^{twi} p_{ppi})$	F	P	P	P	P	P	P	F	P	P	P	P	P	P
y	F	P	P	P	P	P	P	F	P	P	P	P	P	P
Services														
m_{srv}	F	P	P	F	F	P	F	F	P	P	F	F	P	F
y	P	P	P	P	P	P	P	P	P	P	P	P	P	P

Notes: F represents a Fail and P represents a Pass. The first column indicates the dependent variable of the equation that the residuals are generated from. The above conclusions are drawn based on the visual inspection of the correlograms of the residuals.

Consistency with ECM and OLS

For some choices of explanatory variables and lag length we found that the results given by the VECM were inconsistent with those given by the ECM and OLS. We were particularly concerned about sign changes, although these were rare. However, we sought to have a VECM specification that had the same sign as the ECM and OLS and a similar order of magnitude and significance test results to the ECM. In Table C6 we present each VECM estimate and the corresponding ECM estimate.²³

Table C6: Comparison of VECM and ECM Results

	Lags											
	3	4	5	6	7	8						
Exports												
Agricultural												
s_{agr}	-0.2	-0.1	-0.2	-0.1	-0.2	-0.1	-0.2	-0.1	-0.2	-0.1	-0.2	-0.2
y	1.6	1.2	1.7	1.3	1.6	1.4	1.8	1.5	1.8	1.5	1.8	1.6
Resource												
p_{lab}	-5.0	-1.8	-5.6	-2.0	0.7	-1.0	3.5	-0.2	34.9	-0.9	-2.5	-2.0
y	1.5	1.8	1.4	1.9	2.1	1.9	2.4	2.1	5.9	2.0	1.8	1.9
Manufactured												
$p_{cpi}^*/(e^{twi} p_{ppi})$	0.8	0.7	0.9	0.8	0.9	0.7	0.9	0.6	0.7	0.6	0.8	0.7
$T2$	0.007	0.01	0.004	0.01	0.003	0.01	0.004	0.01	0.01	0.01	0.006	0.01
Services												
$p_{cpi}^*/(e^{twi} p_{cpi})$	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
y^*	0.9	1.0	0.9	1.1	0.6	0.9	0.7	0.8	0.6	0.8	0.8	0.9
Imports												
Goods												
$p_{gds}^x/(e^{twi} p_{ppi})$	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.7	-0.8	-0.8
Y	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
Services												
y	1.1	1.0	1.2	0.9	0.9	0.9	1.0	1.0	1.0	0.9	0.2	0.2

Notes: VECM estimates appear in bold, ECM estimates are in plain. Results for 2 Lags are not reported due to space constraints.

²³ The estimates with (static) OLS are not reported here, but the results are in line with those from the VECM and the ECM (results available on request from the authors).

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