Australia-New Zealand Currency Union: A Structural Approach

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Abstract

This paper compares an Australia-New Zealand currency union to a purely floating exchange rate regime in the context of a structural, two-country open economy model. Micro-foundations support policy assessment by facilitating direct calculation of household welfare. Analysis focuses on changing business cycle volatilities; the role of risk is not considered. At benchmark calibration currency union is welfare reducing for both Australia and New Zealand. Sensitivity analyses reveal these results to be qualitatively robust over alternative degrees of shock correlation and shock transmission.

JEL codes: F22, F33, F41, F42

Keywords: currency union, welfare analysis, exchange rate regime, Australia, New Zealand
1 Introduction

This paper compares an Australia-New Zealand currency union to a purely floating exchange rate regime in the context of a structural, two-country open economy model. Each regime is assessed by measuring household welfare. Welfare differences arise between regimes due to changes in business cycle volatilities. Reduced currency risk as a result of currency union is not considered.

Within politics and economics an Australia-New Zealand currency union has previously been considered. Former New Zealand Prime Minister Helen Clark proposed at a United Nations conference in 2000 that ‘such a union might be inevitable’. Crosby and Otto (2002) and Grimes et al. (2000) discussed separately benefits and gains proposed by the currency union literature in an Australia-New Zealand context. In contrast, the model in this paper illustrates transmission and interaction of several of their arguments in a general equilibrium framework that calculates the aggregate outcome. Specifically, the model considers gains from increased price and output stability through reduced nominal exchange rate fluctuations, as well as losses from reduced monetary policy autonomy in terms of stance and coverage. In addition, the model tests assumptions about factor mobility and business cycle symmetry (achieved through shock correlation and transmission) which are two characteristics proposed by the literature as increasing the optimality of a region for currency union (Mundell, 1961).

The New Open Economy Macroeconomics literature motivates a two-country, micro-founded, sticky-price model\(^1\). Price-setting ability is facilitated by monopolistic competition of Blanchard and Kiyotaki (1987) and price rigidities are motivated through price-adjustment costs of Hairault and Portier (1993). Each economy is subject to exogenous transitory shocks. Currency union is modeled as a common monetary policy and elimination of nominal exchange rate fluctuations. The micro-founded model facilitates direct welfare calculation and is therefore particularly useful for policy assessment. In a two-country setting, this traces back to Obstfeld and Rogoff (1995). This paper departs from their model by introducing a distinction between the degree of monopolistic competition and the substitutability between home and foreign economy goods. Corsetti and Pesenti (2001) highlight that if this distinction is absent, households value home and foreign goods equally and the effects of shocks are therefore qualitatively similar independent of their source. In addition, this paper allows for steady state income and population differences, labour mobility and an interest rate rule to dictate monetary policy.

At benchmark calibration currency union is welfare reducing for both Australia and New Zealand. This implies currency union exaggerates fluctuations in welfare variables in both

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\(^1\)A survey of this literature is given in Lane (2001).
countries. Monetary policy shocks dominate benchmark results; however, qualitative results are robust to the removal of monetary policy shocks. Quantitatively results are insignificant and therefore it is concluded that business cycle fluctuations are irrelevant to the exchange rate regime decision for both countries. Sensitivity analyses reveal qualitative results to be robust over alternative calibrations of shock correlation and shock transmission (as dictated by elasticities of substitution between Australian and New Zealand goods and import shares in consumption).

This paper proceeds as follows. Section 2 introduces the model. Section 3 summarises calibrations of the floating regime and currency union models. Section 4 presents quantitative results from the benchmark calibration and disaggregates these results by impulse response function analyses. Sensitivity analyses are also presented which test the robustness of initial results with respect to several factors that determine a region’s optimality for currency union. Section 5 will then conclude.

2 The Model

The agents of each economy are households, three tiers of firms and a central bank. There exist markets for labour, bonds and three types of goods: intermediate, final and consumption goods. Intermediate goods are inputs for final goods. Final goods are internationally traded, and are inputs for consumption goods. Consumption goods are sold domestically to households. The intermediate goods market is monopolistically competitive and all other markets are perfectly competitive.

The home country structure is presented here. The structure of the foreign country is symmetric.

2.1 Households

There exists a continuum of utility-maximising households in each economy. The home country population is normalised to 1 and the foreign country population is scaled by $\theta$ at the equilibrium to reflect relative population differences. Households within an economy have identical preferences and face identical shocks. The behaviour of an economy’s households may therefore be characterised by an infinitely-lived representative. The utility of households is increasing in consumption ($C_t$) and decreasing in labour hours ($h_t$). Labour hours are divided between the home ($\xi_t$) and foreign economies. Total hours worked at home and in the foreign economy are non-separable elements of utility. Households may intertemporally save by purchasing home ($B_t^h$) and/or foreign ($B_t^{h^*}$) bonds, or investing ($I_t$)

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2 The results of the model would be no different if final and consumption good firms were excluded, in favour of households purchasing domestic and foreign intermediate goods directly.
in the physical capital stock for the following period \((K_{t+1})\). Households face investment adjustment costs but no transaction costs on bond purchases. Households own domestic intermediate goods firms and receive positive profits \((\Gamma^h_t)\).

The household’s problem is represented by

\[
\max_{K_{t+1}, B^h_t, B^{hs}_t, C_t, h_t, \xi_t} \sum_{t=0}^{\infty} \beta^t \left[ \eta_t \log C_t - \frac{H^h_t + \mu}{1 + \mu} \right],
\]

s.t.

\[
B^h_t + e_t B^{hs}_t + P_t C_t + P_t I_t \leq R^h_{t-1} B^h_{t-1} + e_t R^{f}_{t-1} B^{hs}_{t-1} + W^h_t \xi_t h_t + e_t W^f_t (1 - \xi_t) h_t
\]

\[
+ z_t K_t - \frac{\psi^I}{2} \left( \frac{I_t}{K_t} - \delta \right)^2 P_t K_t + \Gamma^h_t,
\]

where \(H_t = \xi^h_t (1 - \xi_t)^{1-\alpha} h_t\). This form for labour utility introduces a non-separability between hours worked at home and abroad. The value of \(\alpha\) dictates the relative preference for each. The household independently decides total labour hours and allocation of labour hours. The law of motion of capital is given by \(K_{t+1} = I_t + (1 - \delta) K_t\). \(e_t\) is the nominal exchange rate, \(R^h_t\) is the home gross nominal interest rate and \(W^h_t\) is the home wage. As utility is strictly increasing in consumption, the budget constraint holds with equality in equilibrium. \(\eta_t\) is an AR(1) process for preferences,

\[
\log \eta_t = \rho \log \eta_{t-1} + \omega^h_t \quad \omega^h_t \sim N(0, \sigma_{\omega}).
\]

Country-specific unanticipated changes to preferences are generated through \(\omega^h_t\). The correlation of preference shocks between home and foreign economies is given by \(\rho_{\eta, h}\).

### 2.2 Intermediate Goods Firms

There exists a continuum of intermediate goods firms with population density 1. The intermediate goods firms sell output \((Y^i_t(a))\) domestically to final good firms. The intermediate goods market is monopolistically competitive as per Blanchard and Kiyotaki (1987) with differentiated, but substitutable products. Firms set prices \((P^i_t(a))\) taking a demand constraint as given and face price-adjustment costs of Hairault and Portier (1993), which may be interpreted as menu costs. Price-adjustment costs generate a sticky price response to shocks, giving rise to nominal rigidities in the economy. The discount rate \(\phi_t\) is the real rate of return of the firm and thus the return to the household from ownership of the firm. The assumption of complete asset markets gives rise to non-arbitrage conditions, dictating that all returns to the household must equate in equilibrium. Therefore

\(^3i\) indicates the intermediate market, and \(a\) is the firm index.
\( \phi_t \propto \beta^t \lambda_t \), the household’s discounted marginal utility of wealth.

The firm employs home and foreign labour \((h_t(a))\). Labour is assumed to be homogeneous within and across countries. Labour markets are perfectly competitive.

The problem of the firm is represented by

\[
\max_{P^i_t(a)} E_0 \sum_{t=0}^{\infty} \phi_t \left[ P^i_t(a) Y^i_t(a) - W^h_t h_t(a) - z_t K_t - P^x_t X^H_t \psi \left( \frac{P^i_t(a)}{P^i_{t-1}(a)} - \bar{\pi}^x \right)^2 \right],
\]

where price-adjustment costs are expressed in terms of the economy’s final good. The firm faces the following demand constraint, which derives from the optimality condition of final good firms,

\[
Y^i_t(a) \leq \left( \frac{P^i_t(a)}{P^x_t} \right)^{-\epsilon^i} X^H_t.
\]

Profits are strictly increasing in output, therefore the demand constraint holds with equality in equilibrium. The firm’s production function exhibits constant returns to scale,

\[
Y^i_t(a) = A^h_t K^\zeta_t h_t(a)^{1-\zeta}.
\]

The production technology \(A_t\) is a function of lagged values of home and foreign technologies and is subject to exogenous shocks.

\[
\log A^h_t = \Upsilon \log A^h_{t-1} + (1 - \Upsilon) \log \bar{A}^h + \Upsilon^* \log A^f_{t-1} - \Upsilon^* \log \bar{A}^f + \epsilon^h_t,
\]

\[
\epsilon^h_t \sim N(0, \sigma^\epsilon)
\]

Country-specific unanticipated changes to technology are generated through \(\epsilon^h_t\). The form of the process allows for symmetry in technology to be generated through two avenues. There may exist some international transmission of economy-specific technology shocks (\(\Upsilon^*\)), in addition to some correlation of shocks. The correlation of technology shocks between home and foreign economies is given by \(\rho_{\epsilon^h,\epsilon^f}\). \(\bar{A}^h\) and \(\bar{A}^f\) are steady state values of technology. The model is calibrated such that the steady state values reflect relative steady state per capita income differences between the two economies.

The aggregate index of output across the continuum of intermediate goods firms on the
interval $(0,1)$ is given by
\[
X_t^H = \left[ \int_0^1 Y_t^i(a) \frac{\epsilon_i}{\epsilon_i - 1} \, da \right]^{\frac{\epsilon_i}{\epsilon_i - 1}},
\] (9)
where $\epsilon_i$ is the elasticity of substitution between individual firms’ goods (as production inputs for final good firms). It will turn out that this dictates the degree of monopolistic competition. The intermediate goods price index is given by
\[
P_t^x = \left[ \int_0^1 P_t^i(a)^{1-\epsilon_i} \, da \right]^{\frac{1}{1-\epsilon_i}}.
\] (10)

2.3 Final Good Firms

Final good firms input a bundle of domestically-produced intermediate goods to produce a single final good ($X^H$). They face demand from home and foreign consumption good firms. The market is perfectly competitive, such that they have no price-setting ability and make zero profits. The technology of final good firms is fixed over time.

Final good firms face the problem
\[
\max_{Y_t^i(a)} P_t^x X_t^H - \int_0^1 P_t^i(a) Y_t^i(a) \, da,
\] (11)
where the production function is
\[
X_t^H = \left[ \int_0^1 Y_t^i(a) \frac{\epsilon_i}{\epsilon_i - 1} \, da \right]^{\frac{\epsilon_i}{\epsilon_i - 1}}.
\] (12)

2.4 Consumption Good Firms

Consumption good firms input domestically, New Zealand and rest-of-the-world-produced ($X^h, X^{h*}, X^{rw}$ respectively) final goods to produce a single consumption good ($Y_t$) to sell domestically. Inputs are priced in the producer’s currency, such that there is full exchange-rate pass-through. The consumption good market is perfectly competitive, therefore firms have no price-setting ability and make zero profits. The firm’s technology is fixed over time.
Consumption good firms face the problem

$$\max_{X^h_t, X^{hs}_t, X^w_t} P_t Y_t - P_t^x X^h_t - e_t P_t^{xf} X^{hs}_t - P_t^w X^w_t$$  \hspace{1cm} (13)$$

where $P_t^w$ is the price of imports from the rest of the world in home currency terms. It is subject to exogenous shocks:

$$\log P_t^w = \rho_{rw} \log P_{t-1}^w + TOT_t, \quad TOT_t \sim N(0, \sigma_{TOT})$$  \hspace{1cm} (14)$$

where the correlation of shocks across countries is given by $\rho_{TOT,TOTf}$.

The production function is

$$Y_t = \left[ \varphi_1^{-\rho} X^h_t + \varphi_2^{-\rho} X^{hs}_t + (1 - \varphi_1 - \varphi_2)^{-\rho} X^{rw}_t \right]^{\frac{1}{\rho}}.$$  \hspace{1cm} (15)$$

A home-bias for consumption is observed in the data, therefore the model is restricted to situations where $\varphi_1 > 0.5$. This implies that purchasing power of parity never holds in the model. The elasticity of substitution between home and foreign goods is given by $\frac{1}{1-\rho}$.

The consumption goods price index for the home economy is

$$P_t = \left[ \varphi_1 P_t^{xh} + \varphi_2 \left( e_t P_t^{xf} \right)^{\rho} + (1 - \varphi_1 - \varphi_2) P_t^{rw} \right]^{\frac{1}{\rho}},$$  \hspace{1cm} (16)$$

where $P_t^x$ and $P_t^{xf}$ are each price indices of intermediate goods.

### 2.5 Central Bank

There exists a central bank in each economy setting monetary policy by a Taylor-type interest rate rule, where the nominal interest rate is set in response to differentials from steady state consumption good output and inflation within the domestic economy

$$R^h_t = \left( \frac{R^h_t}{R^h_{t-1}} \right)^{\varsigma} \left[ \left( \frac{Y_t}{Y} \right)^{\gamma_Y} \left( \frac{\pi_t}{\pi} \right)^{\gamma_\pi} \right]^{1-\varsigma} \nu_t, \quad \nu_t \sim N(0, \sigma_\nu).$$  \hspace{1cm} (17)$$

\[4\]Lubik and Schorfheide (2007) find neither the Australian nor New Zealand central banks to respond to exchange rate fluctuations. This conclusion is sustained through several robustness tests and confirmed in subsequent research by Lubik (2007). Exchange rate considerations therefore do not enter the interest rate rule.
Inflation ($\pi_t$) here refers to inflation in the price of consumption goods. $\nu_t$ are exogenous monetary policy shocks. These represent a discretionary element of monetary policy. The correlation of monetary policy shocks between home and foreign economies is given by $\rho_{\nu,\nu^f}$.

2.6 Balance of Payments

The trade account between Australia and New Zealand is defined as net export revenue:

$$TA_t = \theta P^x_t X^f_t - e_t P^x_t X^h_t,$$

where $\theta$ weights foreign country quantity variables to account for population differences.

Let $s_t$ define the real exchange rate,

$$s_t = \frac{e_t P^f}{P_t}.$$

2.7 Equilibrium

The focus is on the symmetric equilibrium, such that intermediate goods firms within a country face the same problem and thus set the same price for any period $t$.

$$P^i_t(a) = P^i_t(a') \quad \forall a, a' \in (0,1)$$

$$P^{if}_t(a) = P^{if}_t(a') \quad \forall a, a' \in (0,1)$$

$$Y^i_t(a) = Y^i_t(a') \quad \forall a, a' \in (0,1)$$

$$Y^{if}_t(a) = Y^{if}_t(a') \quad \forall a, a' \in (0,1)$$

Additionally, a symmetric equilibrium implies:

$$P^i_t(a) = P^z_t \quad \forall a \in (0,1)$$

\(^5\)By definition currency union prescribes a common central bank and thus common interest rate rule. Shocks to monetary policy in currency union are therefore perfectly symmetric by construction.
An equilibrium of this economy is a set of prices

\[ P_t = \left[ P_t, P_t^f, P_t^x, P_t^{x^f}, P_t^{r^w}, P_t^{r^{w^*}}, P_t^i(a), P_t^{ij}(a), W_t, W_t^f, z_t, z_t^f, R_t, R_t^f, e_t \right]_{t=0}^\infty \]

and the sets of quantities

\[ Q^1_t = \left[ Y_t, Y_t^f, X_t^H, X_t^F, Y_t^{ij}(a), Y_t^{ij^*(a)}, X_t^h, X_t^f, X_t^{h^*}, X_t^{f^*}, X_t^{r^w}, X_t^{r^{w^*}}, h_t(a), h_t^f(a) \right]_{t=0}^\infty \]

\[ Q^2_t = \left[ h_t, h_t^f, \xi_t, \xi_t^f, C_t, C_t^f, B_{t+1}^h, B_{t+1}^{h^*}, B_{t+1}^{f^*}, I_t, I_t^f, K_{t+1}, K_{t+1}^f \right]_{t=0}^\infty \]

such that:

1. given the set of prices \( P_t \), the set of quantities \( Q^1_t \) maximises domestic and foreign firms' profit;
2. given the set of prices \( P_t \), the set of quantities \( Q^2_t \) maximises domestic and foreign households' utility;
3. given the sets of quantities \( Q^1_t, Q^2_t \), the set of prices \( P_t \) clears all markets in the sense

\[ Y_t^i(a) = X_t^H \quad \text{(26)} \]

\[ Y_t^{ij}(a) = X_t^F \quad \text{(27)} \]

\[ X_t^H = X_t^h + \theta X_t^{f^*} + X_t^H \frac{\psi}{2} \left( \bar{\pi}^x - \bar{\pi}^x^f \right)^2 \quad \text{(28)} \]

\[ \theta X_t^F = \theta X_t^{ij} + X_t^{h^*} + \theta X_t^{f^*} \frac{\psi}{2} \left( \bar{\pi}^x - \bar{\pi}^x^f \right)^2 \quad \text{(29)} \]

\[ Y_t = C_t + I_t + \frac{P_t^{r^w}}{P_t} X_t^{r^w} + \frac{\psi}{2} \left( \frac{I_t}{K_t} - \delta \right)^2 K_t \quad \text{(30)} \]

\[ Y_t^f = C_t^f + I_t^f + \frac{P_t^{r^{w^*}}}{P_t} X_t^{r^{w^*}} + \frac{\psi}{2} \left( \frac{I_t^f}{K_t^f} - \delta \right)^2 K_t^f \quad \text{(31)} \]

\[ \xi_t h_t + \theta \left( 1 - \xi_t^f \right) h_t^f = h_t(a) = \int_0^1 h_t(a) da \quad \text{(32)} \]

\[ (1 - \xi_t) h_t + \theta \xi_t h_t^f = \theta h_t(a) = \int_0^1 \theta h_t(a) da \quad \text{(33)} \]

\[ B_t^h + \theta B_t^{f^*} = 0 \quad \text{(34)} \]
\[ B_t^{h*} + \theta B_t^f = 0 \]  \hspace{1cm} (35)

where \( \theta \) weights foreign country variables to account for population differences and \( \frac{P_t^{rw}}{P_t} \) is the real exchange rate between the home economy and the rest-of-the-world, denoted in home country currency terms.

### 2.8 Currency Union

Currency union implies a common central bank and fixed nominal exchange rate. The model reflects this in a common market for bonds and setting \( e_t = 1 \). As this model abstracts from money, this is the same as implementing any fixed exchange rate regime. However, the superior credibility of currency union supports the implicit assumption that volatilities of exogenous (financial) shocks do not change as a result of the new exchange rate regime.

### 3 Calibration

#### 3.1 Benchmark Model Calibration

Without loss of generality, it is assumed that both economies display neither growth nor inflation in the steady state. New Zealand’s GDP per capita is around 91% of Australia’s\(^6\). The relative values of steady state technologies \((\bar{A}, \bar{A}^f)\) reflect this ratio to create a difference in steady state household income. New Zealand’s population is 20% the size of Australia’s. \( \theta = 0.2 \) reflects this difference in market size. \( \alpha \) is the intra-temporal elasticity of substitution between working a labour unit domestically and working one abroad. Higher values of \( \alpha \) raise the marginal utility cost of working abroad. \( \alpha, \alpha^f \) are calibrated such that the New Zealand real wage is 83% of that in Australia, given \( \xi(\alpha) \) and \( \xi^f(\alpha^f) \). \( \alpha > \alpha^f \) and \( \xi > \xi^f \) are consistent with the higher movement of New Zealanders to Australia than Australians to New Zealand that is evident in the data. \( \varphi_1 \) and \( \varphi_2 \) give respectively the steady state shares of domestically produced goods and New Zealand produced goods used in the production of consumption goods \((1 - \varphi_1 - \varphi_2 \) gives the steady state share of rest-of-the-world produced goods used in production). National Accounts data gives that around 77% of Australian production inputs are sourced domestically, 0.73% are imported from New Zealand and the remainder are imported from elsewhere. New Zealand sources 70% of production inputs domestically, imports 6.1% from Australia and imports the remainder from elsewhere. For both countries a home-bias in consumption is therefore observed such that Purchasing Power of Parity does not hold. These parameters undergo

sensitivity analyses as their calibration may qualitatively influence results. $\frac{\epsilon^i}{\epsilon_{i-1}} - 1$ gives the average mark-up rate in the economy. $\epsilon^i = 6$ such that the mark-up rate is 20 percent. $\mu$ is the elasticity of total labour disutility. Following estimates of Justiniano and Preston (2004) in a similar structural model of the Australian and New Zealand economies $\mu$ is calibrated at 0.46 for both Australia and New Zealand. Values for $\psi, \psi^f$, the strength of price adjustment costs, are mapped from estimates of Calvo-style price setting by Lubik (2007). Using the optimality conditions of intermediate goods firms we derive $\psi = 161$ for Australia and $\psi^f = 381$ for New Zealand.

Following estimates by Lubik (2007) the elasticities of substitution between home and foreign goods ($\rho$) for both Australia and New Zealand are set to 0.35. This parameter undergoes sensitivity analysis. Following estimates by Preston and Justiniano (2004), $\varsigma$, the persistence in the interest rate, is set to 0.82 for Australia and 0.86 for New Zealand. $\gamma_Y$, the coefficient on the output differential from steady state, is 0.115 for Australia and 0.155 for New Zealand. $\gamma_\pi$, the coefficient on the inflation differential from steady state, is 2.23 for Australia and 2.59 for New Zealand. Following calibration by Nimark and Jaaskela (2008), $\varsigma$ is set such that Australia’s capital share in output is 29%. Following estimation by Munro and Sethi (2007) $\psi^f$ is set such that New Zealand’s capital share in output is 25.4%.

Time series for preferences are derived from each household’s intertemporal consumption decision using consumption, inflation and interest rate data for Australia and New Zealand. Using this preference series persistence, standard deviations and the correlation of preference shocks are estimated. Time series for total factor productivities (technologies) are derived from GDP, labour and physical capital data. Persistence ($\Upsilon, \Upsilon^f$), international transmission ($\Upsilon^*, \Upsilon^{f*}$), standard deviations and the correlation of technology shocks are estimated from these series. Inflation, interest rate and GDP data are used to derive series of monetary policy shocks for Australia and New Zealand. These series are used to derive the correlation of shocks between countries. Persistence, standard deviations and the correlation of exogenous rest-of-the-world terms-of-trade shocks are estimated using trade-weighted real exchange rate data for Australia and New Zealand. It must be noted that each data series includes the other country and therefore estimates are inaccurate to the extent that each economy influences the other’s trade-weighted real exchange rate. New Zealand represents only 3% of Australia’s trade and therefore the degree of inaccuracy is unlikely to be significant for Australian estimates. However, Australia represents 20% of New Zealand’s total trade and therefore estimation results may be treated with some caution. Several shock correlations undergo sensitivity analyses.

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7 Preston and Justiniano’s (2004) estimates of the coefficients on each output gap is 0.46 for Australia and 0.62 for New Zealand; however, this uses annualized GDP data and the model presented here is in quarterly terms, therefore these estimates have been divided by 4.

8 Time series are from Q1:1990 to Q4:2007 from Source OECD (http://www.sourceoecd.org/).
The degree of investment adjustment costs \((\psi^I, \psi^If)\) and the standard deviation of monetary policy innovations \((\sigma_\nu, \sigma_\nu^f)\) for both economies are calibrated simultaneously to match standard deviations of investment to output ratios and inflation.

All calibrated values are given in Appendix 1.

### 3.2 Currency Union Calibration

In currency union there exists a common central bank and therefore single interest rate rule. For the benchmark calibration the most likely behaviour of the central bank in currency union must be determined. There exist two obvious alternatives. The first is an average of the parameter values in the Australian and New Zealand interest rate rules from the benchmark model. The second is to retain the parameter estimates on the Australian interest rate rule from the benchmark model. The second approach relies on the politics of an Australia-New Zealand currency union, therefore the first approach is adopted. The standard deviation of currency union monetary policy shocks is calibrated conservatively to equal that of the country with a higher standard deviation in the benchmark calibration. However, as these shocks represents a discretionary element of monetary policy their standard deviation is endogenous to the new post-union policy environment. Therefore a model without monetary policy shocks is additionally considered.

In addition, Australia and New Zealand’s output and inflation differentials from steady state must be weighted in the common interest rate rule. Again there exist two obvious alternatives. The first assigns a 50 percent weighting to each. The second borrows from Europe a weighting equal to an economy’s share of union GDP. This second regime again relies on the politics of a prospective currency union. Therefore the first weighting is used.

### 4 Results

#### 4.1 A Welfare Criterion

The model provides a micro-founded utility criterion, which facilitates direct calculation of each household’s welfare (see Appendix 3). A social welfare function is not considered, as this paper focuses strictly on policy implications. As in Carre and Collard (2003) the gains (losses) of monetary union are expressed in terms of an expected permanent transfer rate on consumption \(x\):

\[
\mathbb{E} \sum_{t=0}^{\infty} \beta^t u \left( (1 + x) C_t^F, 1 - H_t^F \right) = \mathbb{E} \sum_{t=0}^{\infty} \beta^t u \left( C_t^{CU}, 1 - H_t^{CU} \right),
\]

where \(F\) is the pure floating regime and \(CU\) is currency union. This increases the ease of
interpretation. If currency union is welfare improving, the result is positive \((x > 0)\). In the benchmark model the household would require positive consumption as compensation for bearing the floating regime, rather than currency union.

4.2 Quantitative Analysis

Currency union reduces the welfare of Australian and New Zealand households \((x < 0)\), reflecting overall higher volatility in consumption and labour as a result of the exchange rate regime. However, results are quantitatively small. The New Zealand welfare reduction equates a permanent consumption reduction of \(8.4605 \times 10^{-4}\%\) each quarter which is roughly equivalent to an ice cream at a fast food restaurant every 2.2 years. The Australian welfare reduction equates a permanent consumption reduction of \(1.4826 \times 10^{-4}\%\) each quarter which is an ice cream at a fast food restaurant every 12.7 years. We therefore determine that business cycle fluctuations are an insignificant consideration for both Australia and New Zealand in their choice of exchange rate regime.

Despite the insignificant magnitudes of results, the models provide a framework to understand how currency union might qualitatively influence welfare variables. Variance decomposition suggests monetary policy shocks account for almost all welfare changes (Section 4.3.1). In Australia, the result is driven by a stronger interest rate increase in currency union as a result of reduced autonomy in setting monetary policy. This motivates a stronger reaction of welfare variables. For New Zealand, the calibration of monetary policy shocks predominantly drives results. New Zealand bears a higher standard deviation of monetary policy shocks in currency union due to the conservative calibration choice to adopt Australia’s higher benchmark standard deviation. This increases the magnitude of New Zealand reactions to monetary policy shocks, reducing currency union welfare.

Due to the sensitivity of results to monetary policy shocks and calibrations, the model is solved without monetary policy shocks. Qualitative results are robust to this alternate stochastic environment\(^9\) and quantitatively results improve for both countries; however, they remain insignificant. A variance decomposition for this second form of the model is presented in Appendix 4.

4.3 Impulse Response Function Analysis

4.3.1 Variance Decomposition

Variance decomposition highlights the shocks that most influence results (Table 1). For consumption and labour supply volatilities, those variables that largely determine welfare outcomes, monetary policy shocks consistently account for over 90% of volatility changes.

\(^9\) Technology shock standard deviations replace monetary policy shock standard deviations as free parameters in calibrating the benchmark model.
that result from currency union\textsuperscript{10}. As a consequence of these results, impulse response function analysis is restricted to monetary policy shocks\textsuperscript{11}.

Table 1: Variance Decomposition - Differences between Benchmark and C.U. Models

<table>
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<th>Pref\textsuperscript{f}</th>
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\textbf{4.3.2 Monetary Policy Shocks}

Impulse responses to monetary policy shocks differ in the models for two reasons. Firstly, and most obviously, the response can depend on the exchange rate regime. Secondly, and more subtly, the frequency of shocks is lower under currency union. A floating regime dictates that Australia and New Zealand each experience one monetary policy shock every period. In a currency union there exists only one (common) monetary policy shock every period. To understand the qualitative results it is only relevant to compare a country’s response to its own monetary policy shock under a flexible exchange rate against its response to the common monetary policy shock in currency union. This is the focus of analysis. The Australian response to a New Zealand monetary policy shock effectively disappears in currency union. The same is true for New Zealand’s response to an Australian monetary policy shock.

\textsuperscript{10}From New Zealand’s perspective, in currency union Australian monetary policy shocks cease to exist. Therefore the volatility they produce in currency union is nil. For New Zealand, the difference in volatilities between an Australian (floating regime) shock and a currency union shock is simply the volatility in the benchmark model (as currency union volatility is nil). The same is true for Australia in reaction to New Zealand (benchmark model) monetary policy shocks. This is discussed further in section 4.3.2.

\textsuperscript{11}The variance decomposition is presented for up to eight cumulative quarters. If results are extended to 20 and 40 cumulative quarters, results are broadly unchanged from those at 8 quarters.
A positive interest rate shock increases the return on saving thereby decreasing current-period consumption. Instantaneous nominal appreciation of the Australian currency occurs through uncovered interest parity. As prices are unable to fully absorb the shock in the short run, this appreciation is initially real. Production is predominantly demand-driven in the short-run. In response to the consumption fall Australian production and labour demand reduce. Australian prices decline; however, the decline is smaller than that which would be observed if prices were fully-flexible. Demand for New Zealand production falls; however, the effect is marginal due to a home-bias in Australian consumption as well as expenditure-switching towards New Zealand goods as a result of the Australian appreciation. Australia’s trade account therefore deteriorates. In general equilibrium the marginal product of capital, and therefore the rental rate, decline. This drives a fall in the household’s Tobin’s q, motivating a fall in investment and the subsequent-period capital stock. Australian labour supply falls in reaction to the reduced wage. However, the relative wage increases as a result of the real Australian appreciation, motivating an increased share of labour hours to be worked in Australia. Through the interest rate rule, falling inflation and output dampen the initial shock to the interest rate (Figure 1).

The New Zealand reaction to a New Zealand monetary policy shock under a flexible exchange rate regime qualitatively matches the Australian reaction to an Australian monetary policy shock, as described above (Figure 2).

The Australian reaction is broadly stronger under currency union than with a flexible exchange rate. When New Zealand is also considered for monetary policy, the dampening influence that falling inflation has on the interest rate is lessened; consequently, the interest rate rises by more. Real exchange rate adjustment comes only as a result of relative price movements, as the nominal exchange rate is fixed. New Zealand prices are stickier and therefore the immediate price response to the fall in consumption is smaller than that in Australia. In contrast to the flexible exchange rate model, the Australian currency depreciates in real terms. Despite some expenditure-switching towards Australian production, the Australian trade balance still deteriorates as a consequence of Australia’s larger market size. Labour migrates to New Zealand as the competitiveness of the New Zealand wage improves.

Despite a more volatile interest rate, the New Zealand reaction in currency union is broadly weaker than under a floating regime. The smaller Australian depreciation reduces the expenditure-switching effect such that New Zealand production declines by less. Therefore New Zealand labour demand, wages and labour supply fall by less. The welfare reduction as a result of currency union predominantly derives from calibrating the standard deviation of currency union monetary policy shocks to match that of Australia in the benchmark model, as discussed.
Figure 1: Impulse Response Functions to an Australian Monetary Policy Shock

Blue indicates the floating model and green indicates currency union
Figure 2: Impulse Response Functions to a New Zealand Monetary Policy Shock

Blue indicates the floating model and green indicates currency union
4.4 Sensitivity Analyses

Sensitivity analyses are conducted on those parameters most likely to influence welfare results of currency union. These are the characteristics proposed by the literature as determining a region’s optimality for currency union: factor mobility and business cycle symmetry (achieved by shock correlation as well as shock transmission). Qualitative results are robust to most parameters tested, over reasonable ranges. Exceptions are $\alpha$, the degree of Australian labour mobility, and $\frac{1}{1-\rho}$, the elasticity of substitution between home and foreign production. As Australian labour becomes more mobile ($\alpha$ reduces), currency union becomes increasingly welfare improving (Figure 3). As $\rho$ goes to 1, volatility reduction from currency union becomes infinitely welfare improving as goods approach perfect substitutability (Figure 7).

As shock correlations $\rho_{pref}$ and $\rho_{tech}$ increase, the cost of losing autonomous monetary policy lessens (Figures 4 and 5). The welfare loss of currency union therefore reduces. Changing import shares $\varphi$ and elasticities of substitution between home and foreign goods $\rho$ effectively changes the degree of shock transmission. Depending on the relative volatility of the other country, this can increase or decrease fluctuations in welfare variables as well as influencing the coordination of business cycles. Currency union’s impact on exchange rate volatility and the structure and strength of monetary policy therefore become either more or less important. As New Zealand imports an increasing share of production goods from Australia (as $\varphi_2$ increases) results improve for Australia and New Zealand. However, as Australia imports an increasing share of production goods from New Zealand (as $\varphi_2$ increases) the Australian result increases but the New Zealand result declines (Figure 6).

Figure 3: Response of ‘x’ to variations in $\alpha, \alpha_f$

![Graph](image-url)
Figure 4: Response of ‘x’ to variations in $\rho_{\text{pref}}$

Figure 5: Response of ‘x’ to variations in $\rho_{\text{tech}}$
Figure 6: Response of ‘x’ to variations in $\varphi_{MP}$
Figure 7: Response of ‘x’ to variations in $\rho$

![Graph showing the response of x to variations in rho.](image-url)
5 Conclusion

This paper has compared an Australia-New Zealand currency union to a purely floating exchange rate regime in the context of a structural, two-country open economy model. Micro-foundations of the model allowed for direct calculation of household welfare, which is used to assess relative gains and losses from currency union.

Qualitatively, currency union increases welfare variable volatilities in Australia and New Zealand and is therefore welfare reducing for households in both countries. However, results are quantitatively insignificant, suggesting business cycle fluctuations are irrelevant to Australia and New Zealand’s decision of the optimal exchange rate regime. Sensitivity analyses revealed qualitative results to be robust over alternative calibrations of shock correlation and shock transmission (as dictated by elasticities of substitution between Australian and New Zealand goods and import shares in consumption). In addition, qualitative results were robust to the removal of monetary policy shocks from the model, which dominate benchmark results.

The simple structure of the model allowed for tractable analysis; however, there are several additions that may be interesting for further research. Analysis focused on the impact of business cycle volatilities and made no attempt to consider changes in currency risk as a result of currency union. In doing so, several hypotheses of the currency union literature were ignored - namely gains from removing hedging costs and enhanced certainty and price transparency. It may be interesting to adapt the tractable model in this paper to consider how these elements might influence shock transmission in the economy. In addition, fiscal policy plays no role in this paper. However, Gali and Monacelli (2008) demonstrate the stabilisation role of country-specific fiscal policy in a currency union model featuring a continuum of small open economies. It may be interesting to assess how qualitative results change by augmenting the model with a government sector. Finally, Carre and Collard (2003) show that welfare implications of currency union are highly sensitive to the degree of pricing-to-market behaviour, as first introduced by Devereux and Engel (1998) as a consideration when determining the optimal exchange rate regime.
References


Economics Working Papers.

Economy, 624–660.
6 Appendix 1 - Calibration

Table 2: Benchmark Calibration Parameter Values

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Figure 8: Impulse Response Function to an Australian Monetary Policy Shock

Blue indicates the floating model and green indicates currency union.
Figure 9: Impulse Response Function to a New Zealand Monetary Policy Shock

Blue indicates the floating model and green indicates currency union.
8 Appendix 3 - The Calculation of Welfare

Currency union presents a permanent structural change therefore to assess the welfare implications of such a policy it is reasonable to measure average welfare over the full evolution of the economy. Technically this translates to taking an unconditional (on an information set at any time t) expectation over the infinite horizon. As shocks are transitory, welfare becomes a function of the economy’s steady state and the variances of preferences ($\eta$, $\eta^f$), consumption ($C$, $C^f$), labour supply ($h$, $h^f$) and labour location ($\xi$, $\xi^f$). The Australian household’s welfare is given by:

$$Welfare^h = \bar{\eta} \log \bar{C} + \frac{\log \bar{C}}{2} \sigma_\eta^2 + \frac{\bar{\eta}}{2C} \sigma_c^2 + \frac{\sigma_{c\eta}}{C} - \bar{\eta} \frac{1}{2C^2} \sigma_c^2$$  \hspace{1cm} (37)

$$- \left[ \frac{1}{1 + \delta} \left( \bar{\xi}^\alpha (1 - \bar{\xi})^{1-\alpha} \xi \right)^{1+\delta} + \frac{\bar{H}^{1+\delta}}{2h} \sigma_h^2 + \frac{1}{2} \bar{\xi} \left( \frac{1 - \alpha}{1 - \bar{\xi}} \right) \sigma_\xi^2 + \frac{\delta \bar{H}^{1+\delta}}{2} \bar{\xi} \sigma_\xi^2 \right]$$  \hspace{1cm} (38)

$$- \left[ (1 + \delta) \frac{\bar{H}^{1+\delta}}{h} \left( \frac{\alpha}{\xi} - \frac{1 - \alpha}{1 - \bar{\xi}} \right) \sigma_h \xi + \frac{1}{2} \left( (1 + \delta) \bar{H}^{1+\delta} \left( \frac{\alpha}{\xi} - \frac{1 - \alpha}{1 - \bar{\xi}} \right)^2 - \left( \frac{\alpha}{\xi^2} - \frac{1 - \alpha}{(1 - \bar{\xi})^2} \right) \bar{H}^{1+\delta} \right) \sigma_\xi^2 \right]$$  \hspace{1cm} (39)

To obtain the welfare function, one takes a second-order Taylor expansion of the household’s utility function. Remaining variables are log-linearised around the steady state. Moments higher than second-order are not considered, as their impact on welfare is close to 0. This method generates a welfare function in the same terms as the economy’s characteristic equations, when the model is solved. The steady state does not change as a result of currency union. This is due to both transitory shocks centered around 0, and because the model is solved to the first-order, therefore risk changes between the two policies are not considered at the steady state.

28
9 Appendix 4 - Variance Decomposition of Model Without Monetary Policy Shocks

The variance decomposition is presented for up to eight cumulative quarters. If results are extended to 20 and 40 cumulative quarters, results are broadly unchanged from those at 8 quarters.

Table 3: Variance Decomposition - Differences between Benchmark and C.U. Models

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10 Technical Appendix

10.1 First-Order Conditions

The following deflated equations characterise the equilibrium path of the benchmark model.

Household inter-temporal Euler equation (symmetric for the foreign household):

$$\beta E_t \frac{\eta_{t+1}}{C_{t+1}} \left[ E_t z_{t+1} + 1 - \frac{\psi_I}{2} \left( E_t I_{t+1} - \delta \right)^2 + \psi_I E_t K_{t+2} \left( \frac{I_{t+1}}{K_{t+1}} - \delta \right) \right] = \frac{\eta_t}{C_t} \left[ 1 + \psi_I \left( \frac{I_t}{K_t} - \delta \right) \right]$$

(40)

Equivalent returns from investing in bonds or capital (symmetric for the foreign household):

$$E_t \frac{\eta_{t+1}}{C_{t+1}} \left[ E_t z_{t+1} + 1 - \frac{\psi_I}{2} \left( E_t I_{t+1} - \delta \right)^2 + \psi_I E_t K_{t+2} \left( \frac{I_{t+1}}{K_{t+1}} - \delta \right) \right] = E_t \frac{R_{h}^{t} \pi_{t+1}}{\pi_{t+1}} \left[ 1 + \psi_I \left( \frac{I_t}{K_t} - \delta \right) \right]$$

(41)

Intra-temporal labour-consumption decision (given for home and foreign households):

$$H_t^{1+\mu} \frac{h_t}{h_t} = \frac{\eta_t}{C_t} \left[ \xi_t w^h_t + (1 - \xi_t) s_t w^f_t \right]$$

(42)

$$H_t^{1+\mu} \frac{h_t}{h_t} = \frac{\eta_t}{C_t} \left[ \xi_t^f w^f_t + (1 - \xi_t^f) \frac{w^h_t}{s_t} \right]$$

(43)

Allocation of labour between Australia and New Zealand (given for home and foreign households):

$$s_t w^f_t \frac{(1 - \xi_t)}{1 - \alpha} = \frac{w^h_t \xi_t}{\alpha}$$

(44)

$$w^h_t \frac{(1 - \xi_t^f)}{1 - \alpha^f} = \frac{s_t w^f_t \xi_t^f}{\alpha^f}$$

(45)

Perfect risk sharing (only one condition):

$$E_t \frac{\lambda_{t+1}^f}{\lambda_t^f} = E_t \frac{s_{t+1} \pi_{t+1} \lambda_{t+1}}{s_t \pi_{t+1} \lambda_t}$$

(46)

Uncovered interest parity (log-linearised, only one condition):

$$\hat{R}_t^h = E_t \hat{\Delta}_{t+1} + \hat{R}_t^f,$$

(47)

Intermediate goods firms optimality conditions (in equilibrium, symmetric for the foreign firms):

$$X_t^H (1 - \epsilon^i) + \epsilon^i \left( \frac{w_t h_t}{1 - \alpha} + \frac{z_t K_t}{\alpha} \right) - \pi_t^x X_t^H \psi (\pi_t^x - \tilde{\pi}^x) + E_t \left[ \frac{\phi_{t+1}}{\phi_t} \frac{z_t^2}{\phi_{t+1}^2} X_{t+1}^H \psi (\pi_{t+1}^x - \tilde{\pi}^x) \right] = 0.$$  

(48)
\[
\frac{w_t}{z_t} = \frac{1 - \alpha}{\alpha} \frac{K_t}{h_t} \quad (49)
\]

Consumption good firms optimality conditions (home and foreign economies given):

\[
X_t^h = \left( \frac{1}{p_t^h} \right)^{\frac{1}{1-\rho}} \varphi_1 Y_t \quad (50)
\]

\[
X_t^{h*} = \left( \frac{1}{s_t p_t^{fj}} \right)^{\frac{1}{1-\rho}} \varphi_2 Y_t \quad (51)
\]

\[
X_t^{rw} = \left( \frac{1}{p_t^{rw}} \right)^{\frac{1}{1-\rho}} (1 - \varphi_1 - \varphi_2) Y_t \quad (52)
\]

\[
X_t^f = \left( \frac{1}{p_t^f} \right)^{\frac{1}{1-\rho}} \varphi_1^f Y_t^f \quad (53)
\]

\[
X_t^{f*} = \left( \frac{s_t}{p_t^f} \right)^{\frac{1}{1-\rho}} \varphi_2^f Y_t^f \quad (54)
\]

\[
X_t^{frw} = \left( \frac{1}{p_t^{frw}} \right)^{\frac{1}{1-\rho}} (1 - \varphi_1^f - \varphi_2^f) Y_t^f \quad (55)
\]

### 10.2 Log-Linearised Conditions Characterising the Equilibrium Path

The following deflated and log-linearised equations characterise the equilibrium path of the benchmark model. The system is over-identified and therefore one Euler equation is dropped when solving the model. A bar over a variable indicates that variable in the steady state. A hat indicates the log-deviation of that variable from its steady state.

Household inter-temporal Euler equation (symmetric for the foreign household):

\[
\beta (1 - \beta (1 - \delta)) \hat{z}_{t+1} + \beta [1 - (1 - \delta) (\beta - 1)] \left( \hat{\eta}_{t+1} - \hat{C}_{t+1} \right) + \beta \psi^l \delta \left( \hat{I}_{t+1} - \hat{K}_{t+1} \right) = \hat{\eta}_t - \hat{C}_t + \psi^l \delta \left( \hat{I}_t - \hat{K}_t \right)
\]

Equivalent returns from investing in bonds or capital (symmetric for the foreign household):

\[
(1 - \beta (1 - \delta)) \hat{z}_{t+1} + \psi^l \delta \hat{I}_{t+1} - \delta \psi^l \delta \hat{K}_{t+1} = \frac{\hat{R}_t}{\beta} - \frac{\hat{\pi}_{t+1}}{\beta} + \frac{\psi^l}{\beta} \hat{I}_t - \frac{\psi^l}{\beta} \hat{K}_t
\]

Intra-temporal labour-consumption decision (given for home and foreign households):

\[
\left[ (\alpha - \frac{(1 - \alpha) \xi}{1 - \xi}) (1 + \mu) \hat{\xi}_t + \mu \hat{h}_t \right] \frac{\hat{H}^{1+\mu}}{\hat{h} (1 - \xi)} = \frac{\hat{\eta}}{\bar{C}} \left[ \hat{\eta} + \hat{C}_t + \frac{\alpha}{1 - \alpha} \left( \hat{\xi}_t + \hat{w}_t^h \right) + \hat{s}_t + \hat{w}_t^f - \frac{\bar{\xi}}{1 - \xi} \hat{\xi}_t \right]
\]
\[
\left[ \left( \alpha^f - \frac{(1 - \alpha^f) \xi^f}{1 - \xi^f} \right) \left( 1 + \mu^f \right) \xi^f + \mu^f \hat{h}_t \right] \frac{\vec{H}^{f1+\mu^f}}{h^f (1 - \xi^f)} =
\]
\[
\frac{\eta^f}{C^f} \left[ \frac{\eta^f + \hat{C}_t^f}{1 - \alpha^f} + \frac{\alpha^f}{1 - \alpha^f} \left( \xi^f + \hat{w}_t^f \right) + \hat{w}_t^h - \hat{s}_t - \frac{\xi^f}{1 - \xi^f} \hat{f}^f \right]
\]

Allocation of labour between Australia and New Zealand (given for home and foreign households):
\[
\hat{\xi}_t = (1 - \bar{\xi}) \left( \hat{w}_t^f + \hat{s}_t - \hat{w}_t^h \right)
\]
\[
\hat{\xi}_t^f = (1 - \bar{\xi}^f) \left( \hat{w}_t^h - \hat{s}_t - \hat{w}_t^f \right)
\]

Perfect risk sharing (only one condition):
\[
\hat{n}_t + \hat{s}_t - \hat{C}_t = \hat{n}_t^f - \hat{C}_t^f
\]

Uncovered interest parity (only one condition):
\[
\hat{R}_t^h = E_t \hat{\Delta}_{t+1} + \hat{R}_t^f
\]

Law of motion of capital (symmetric for foreign country):
\[
\hat{K}_{t+1} = \delta \hat{I}_t + (1 - \delta) \hat{K}_t
\]

Intermediate goods firms optimality conditions (in equilibrium, symmetric for the foreign firms):
\[
\hat{w}_t - \hat{z}_t = \hat{K}_t - \hat{h}_t
\]
\[
\hat{z}_t^x = \beta E_t \hat{z}_{t+1}^x + \frac{\hat{e}^t - 1}{\psi} \left[ \frac{1}{2 \alpha} \left( \hat{w}_t + \hat{h}_t + \hat{z}_t + \hat{K}_t \right) - \frac{\hat{p}_t^f}{\alpha} - \hat{X}_t^H \right]
\]

Production function (in equilibrium, symmetric for foreign firms):
\[
\hat{X}_t^H = \hat{A}_t + \zeta \hat{K}_t + (1 - \zeta) \hat{h}_t
\]

Zero-profit condition of consumption good firms (given for home and foreign firms):
\[
0 = \varphi_1 \hat{p}_t^{x_1} \hat{p}_t^{x_1} \hat{p}_t^{x_1} + \left( \varphi_1 + \varphi_2 - \varphi_1 \hat{p}_t^{x_1} \hat{p}_t^{x_1} \right) \left( \hat{s}_t + \hat{r}_t^{x1} \right) + (1 - \varphi_1 - \varphi_2) \hat{p}_t^{x1}
\]
\[
0 = \varphi_1 \hat{p}_t^{x_1} \hat{p}_t^{x_1} \hat{p}_t^{x1} + \left( \varphi_1 + \varphi_2 - \varphi_1 \hat{p}_t^{x_1} \hat{p}_t^{x1} \right) \left( \hat{p}_t - \hat{s}_t \right) + (1 - \varphi_1 - \varphi_2) \hat{p}_t^{x1}
\]
Consumption good firms optimality conditions (given for home and foreign firms):

\[
\dot{X}_t^h = \frac{\hat{p}_t^h}{\rho - 1} + \dot{Y}_t
\]

\[
\dot{X}_t^{hs} = \frac{\hat{s}_t^h + \hat{p}_t^x}{\rho - 1} + \dot{Y}_t
\]

\[
\dot{X}_t^{rw} = \frac{\hat{p}_t^{rw}}{\rho - 1} + \dot{Y}_t
\]

\[
\dot{X}_t^f = \frac{\hat{p}_t^x}{\rho^f - 1} + \dot{Y}_t
\]

\[
\dot{X}_t^{fs} = \frac{\hat{s}_t^f + \hat{p}_t^x}{\rho^f - 1} + \dot{Y}_t
\]

\[
\dot{X}_t^{frw} = \frac{\hat{p}_t^{frw}}{\rho^f - 1} + \dot{Y}_t
\]

Central Bank interest rate rule (symmetric for the foreign central bank):

\[
\hat{R}_t = \varsigma \hat{R}_{t-1} + (1 - \varsigma) \left[ \gamma_y \hat{Y}_t + \gamma_\pi \hat{\pi}_t \right] + \nu_t
\]

Final good market clearing condition (given for home and foreign economies):

\[
\dot{X}_t^H = \frac{\dot{X}_t^h}{\dot{X}_t^H} + \theta \frac{\dot{X}_t^{hs}}{\dot{X}_t^H} \dot{X}_t^{fs}
\]

\[
\theta \dot{X}_t^F = \theta \frac{\dot{X}_t^f}{\dot{X}_t^F} + \frac{\dot{X}_t^{hs}}{\dot{X}_t^F} \dot{X}_t^{hs}
\]

Consumption good market clearing condition (symmetric for the foreign economy):

\[
\dot{Y}_t = \frac{C}{\bar{C}} \hat{C}_t + \frac{I}{\bar{I}} \hat{I}_t + \left( 1 - \frac{C}{\bar{C}} - \frac{I}{\bar{I}} \right) \left( \hat{p}_t^{rw} + \dot{X}_t^{rw} \right)
\]

Labour market clearing conditions (given for the home and foreign economies):

\[
\hat{\xi}_t + \hat{h}_t + \theta \frac{\hat{h}_t}{\hat{h}} \left[ \frac{1 - \xi^f}{\xi} \hat{h}_t - \frac{\xi^f}{\xi} \hat{\xi}_t \right] = \left[ 1 + \theta \frac{(1 - \xi^f) \hat{h}_t}{\xi} \right] \hat{h}_t^{dem}
\]

\[
\frac{\hat{h}}{\hat{h}^f} \left[ \frac{1 - \xi^f}{\xi} \hat{h}_t - \frac{\xi^f}{\xi} \hat{\xi}_t \right] + \theta \left( \hat{\xi}_f + \hat{h}_t^f \right) = \left[ 1 - \frac{\xi^f}{\xi^f} \hat{h}_t^f + \theta \right] \hat{h}^{dem}_t
\]

Exogenous variables (symmetric for the home and foreign economies):

\[
\hat{\eta}_t = \hat{\eta}_{t-1} + \omega^h_t, \quad \omega^h_t \sim N \left( 0, \sigma^\omega \right)
\]
\[ \hat{A}_t^h = \Theta \hat{A}_{t-1}^h + \Theta^* \hat{A}_{t-1}^f + \varepsilon_t^h, \quad \varepsilon_t^h \sim N(0, \sigma) \]
\[ \hat{P}_{rw}^t = \rho_{rw} \hat{P}_{rw}^{t-1} + TOT_t, \quad TOT_t \sim N(0, \sigma_{TOT}) \]

Price equations (only one condition for each):
\[ \hat{p}_t^x = \hat{p}_{t-1}^x + \hat{\pi}_t^x - \hat{\pi}_t \] (56)
\[ \hat{p}_t^{xf} = \hat{p}_{t-1}^{xf} + \hat{\pi}_t^{xf} - \hat{\pi}_t^f \] (57)
\[ \hat{s}_t = \hat{s}_{t-1} + \hat{\Delta}_t + \hat{\pi}_t^f - \hat{\pi}_t \] (58)