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Pessimism Shocks in a Model of Global Macroeconomic Interdependence

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Abstract

Insights into the four-region strategic behaviour that drives global economic performance can be derived from applications of the elemental multi-region, macroeconomic simulation model introduced in this paper. It has a global general equilibrium structure that embodies bilateral linkages between represented regions via *both* trade and investment. It is applied to strategic monetary policy during the post-GFC period, which has been characterised in the US, the EU and Japan by increased aversion to downside risk, the stochastic equivalent of pessimism over prices, disposable income levels and capital returns. The retention of full employment in the pessimistic regions is shown to require very considerable monetary expansions and these tend to flood the other regions with liquidity, temporarily raising their terms of trade, real consumption and investment while appreciating their real exchange rates. The results further suggest elements of a coordination game structure amongst the big four economies in which equilibria are characterised by collective monetary responses and deviations are punished via reduced output and employment.

Keywords: pessimism shocks, macroeconomic coordination, China, unconventional monetary policy, spill-overs

1. Introduction

Critical to understanding the behaviour of the global economy is the interaction between the macroeconomic policy regimes of the major economic regions, the US, the Western Europe and Japan, recently joined by China. These regions are all "large" in that the policies of each affect the others as a group as well as the world's many smaller economies. Their behaviour is therefore highly interactive and strategic. The rise of China and other Asian, heretofore developing, economies since the 1980s has not only underwritten global economic performance but high East Asian saving rates have contributed to what became known as the "Asian savings glut" (Note 1) Global real interest rates peaked in the mid-1980s and have fallen since, in part because of this relative increase in global savings supply. Graduation into this group of large economies engenders a transition in the macroeconomic policy toolkit since no longer can governments and central banks rely on "small open economy" trade policy or exchange rate adjustment regimes without the prospect of retaliation from abroad (Note 2).

To capture these large economy interactions and the associated strategic aspects of macroeconomic policy formation this paper introduces a multi-region general equilibrium model that incorporates elemental macroeconomic behaviour. Importantly, the model embodies not only full matrices of trade flows but also bilateral relationships between savers one region and investment in others that allow for the mobility of investable funds while at the same time accommodating the Goldstein-Horioka association between home saving and home investment. The section to follow offers a brief review of global macroeconomic issues and Section 3 details the model. The illustrative analysis of deflationary expectations is discussed in Section 4 and conclusions are offered in Section 5.

2. Global Macroeconomic Policy Interaction

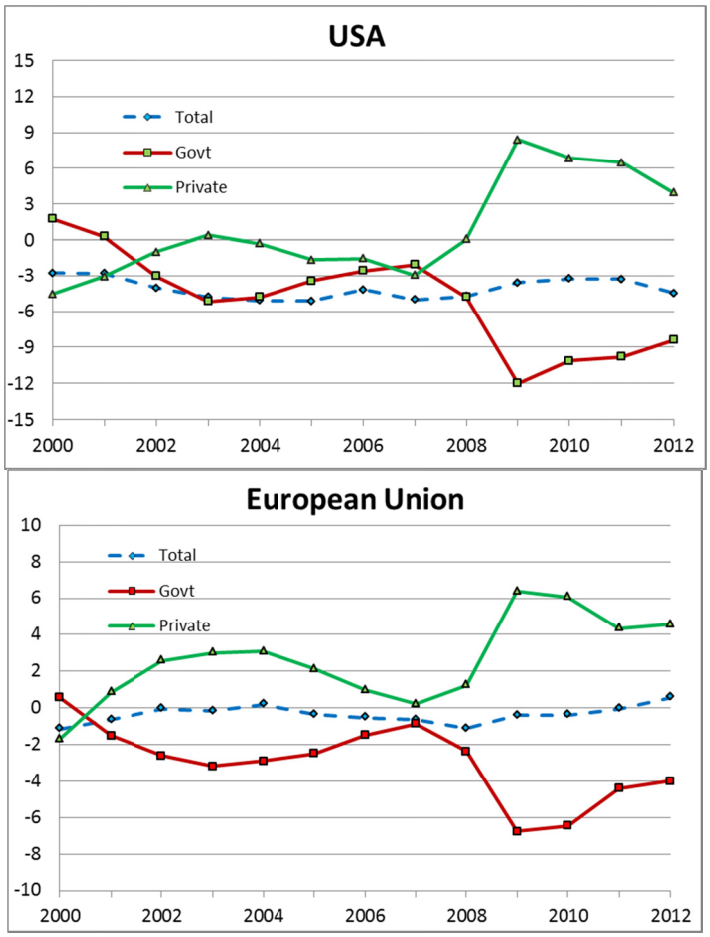
Despite its declining share of global economic activity, the relative openness of the US economy has seen it continue to dominate global financial markets. Though unpalatable economic developments since 2007 have tended to be been blamed on the GFC, the broad pattern of international financial flows does not appear to have been permanently changed by it. Most importantly, the GFC foreshadowed a reversion to net saving positions by

the private sectors of the US, the EU and Japan, while their governments took on net borrowing positions, as shown in Figure 1. As Figure 2 shows, private debt, some of which had been unsustainable, was replaced by sovereign debt, some of which remains unsustainable, leaving heightened global uncertainty as to sovereign financing.

Prior to 2005, the large US current account deficit had been financed by surpluses in Japan and the oil producing countries. Subsequently, and until after the GFC, China carried the largest share of the burden, as shown in Figure 3. China's spectacular growth at that time saw it join the club of large advanced economies by 2010. Thereafter, China's current account surplus began to decline with the shifts in its domestic saving-investment balance associated with its transition to a more inward-focussed regime (Note 3). Nonetheless, both China and Japan remain substantial buyers of US debt and equities, highlighting the potential for disruption in US and global financial markets should their excess saving continue to decline (Note 4).

2.1 Global Finance over Two Decades

Considering the size and comparative openness of the US financial market, its performance is reflective of global financial health. Changes leading up to and in the period beyond the GFC are suggested by Figure 4, which shows the yields on short and long term US Treasury bonds since the beginning of the 1990s. Consistent with the segmentation theory of the yield curve (Johnson et al., 2010), long rates are not merely the commonly claimed (Borio and Disyatat 2011) expectational extensions of short policy rates. The transaction cost of financing long term investments via a succession of short contracts is prohibitive, allowing short and long maturity instruments to trade at prices and yields that differ beyond what would be expected from time preference and expectations forces (Shiller et al., 1983; He & McCauley, 2013). Short bonds primarily serve domestic financial sectors and are instruments of conventional domestic monetary policy. Movements in their yields show their clear links to region-specific business cycles. Long bonds, by contrast, arbitrage with the major instruments of private saving and investment and are extensively traded internationally. Their yields tend therefore to be more stable through time than short yields and reflect movements in the equilibrium between global saving and investment (Note 5).



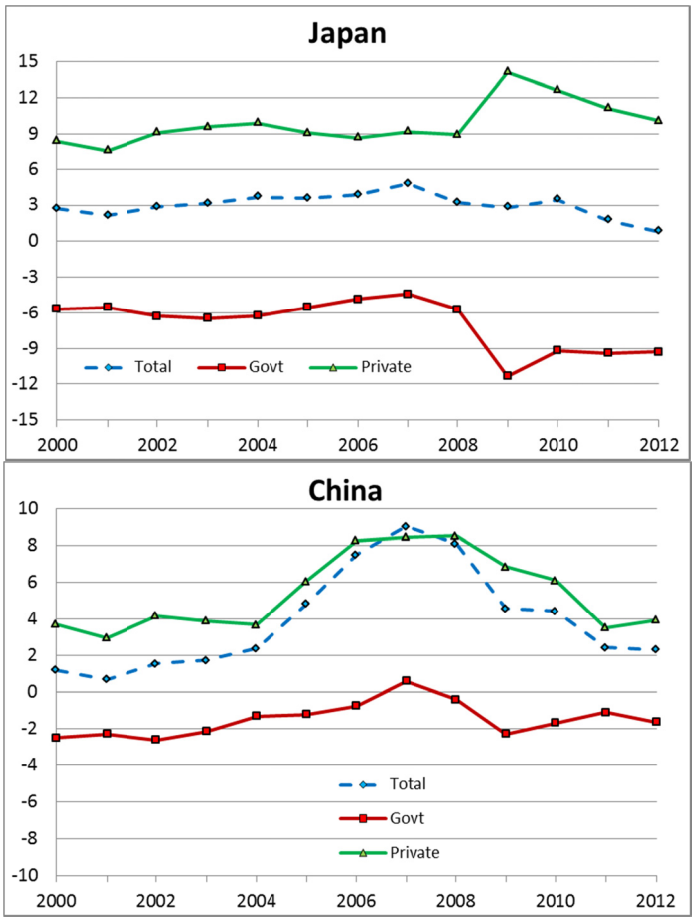


Figure 1. Net private and government saving in the four largest economies, % GDP

Sources: IMF IFS data base; Australia, ABS; China (Mainland, for 2012 authors' estimate is used for net factor income), NBS; USA, Bureau of Economic Analysis; Japan, BOJ; EU, Eurostat.

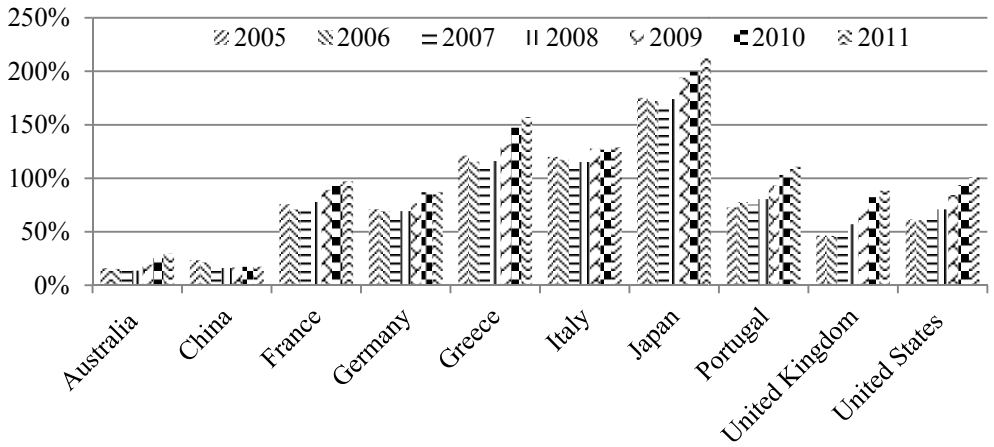


Figure 2. Sovereign debt to GDP ratios for selected countries

Source: OECD Economic Outlook 89 database and *The Economist*.

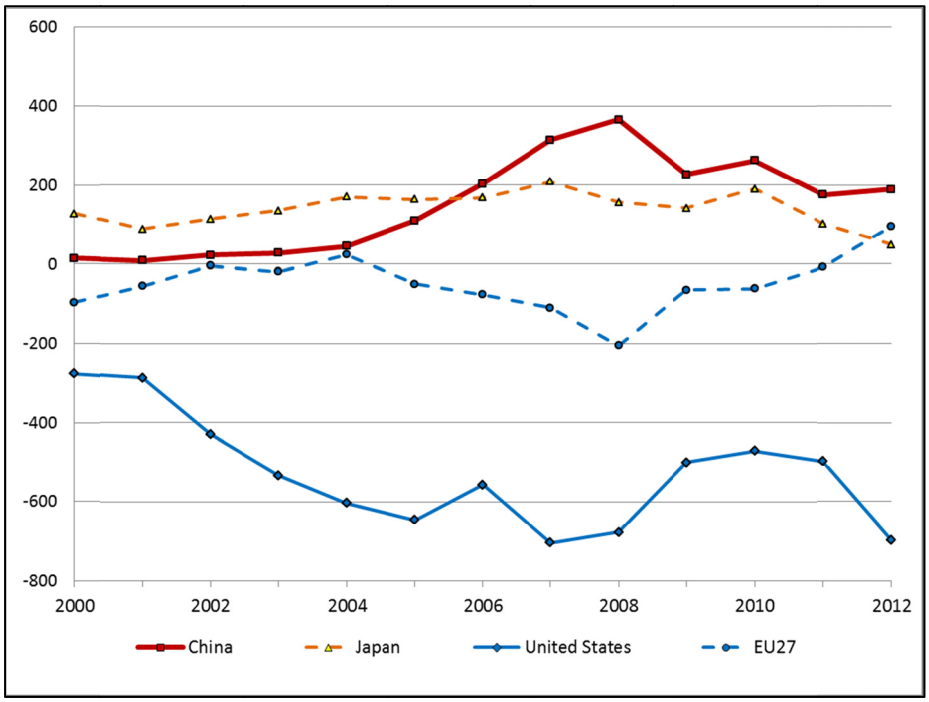


Figure 3. Excess annual saving (current account balances) by key region, US$ billions

Sources: IMF IFS data base; China NBS; Japan, BOP and Ministry of Finance; EU27, Eurostat; US, Bureau of Economic Analysis.

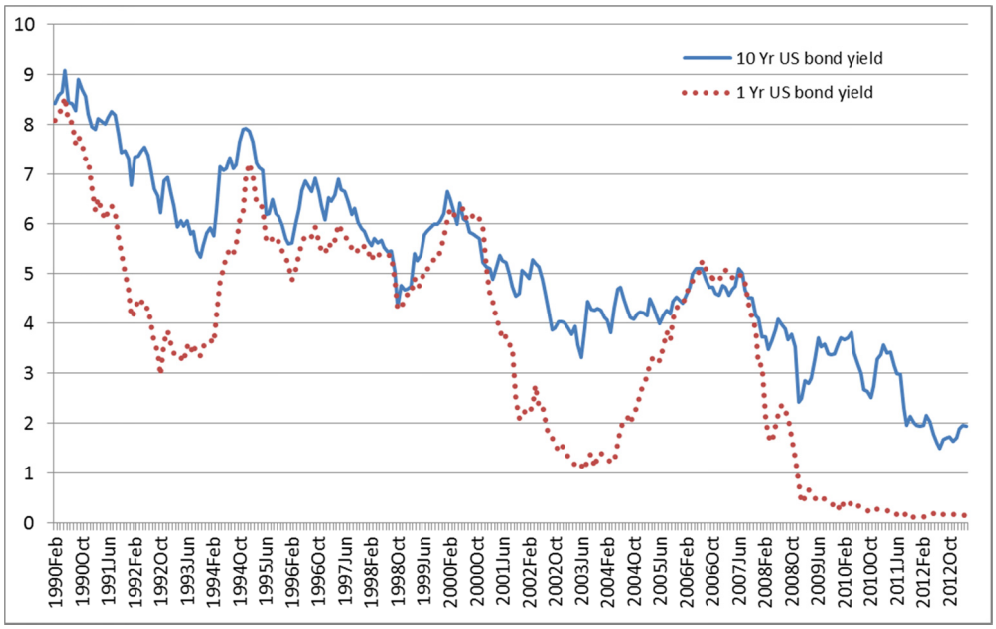


Figure 4. US treasury bond yields over two decades

Source: US Treasury.

Considering that Asia's saving rates have been, and continue to be, substantially higher than those in the rest of the world, and that most of the world's incremental economic growth since the early 1980s has been in Asia (Note 6), it is arguable that the trend decline in long yields reflects an associated decline in the Wicksellian (1898) fundamental interest rate for the world as a whole (Note 7). This view is disputed, particularly as it pertains to the Bernanke (2009) savings glut theory of the GFC, which posited that policy-bolstered excess saving in Asia during the decade after the Asian financial crisis in 1998 reduced global yields and encouraged risky investment in the US and Europe. Persuasive alternative hypotheses concerning the origins of the GFC have since been put

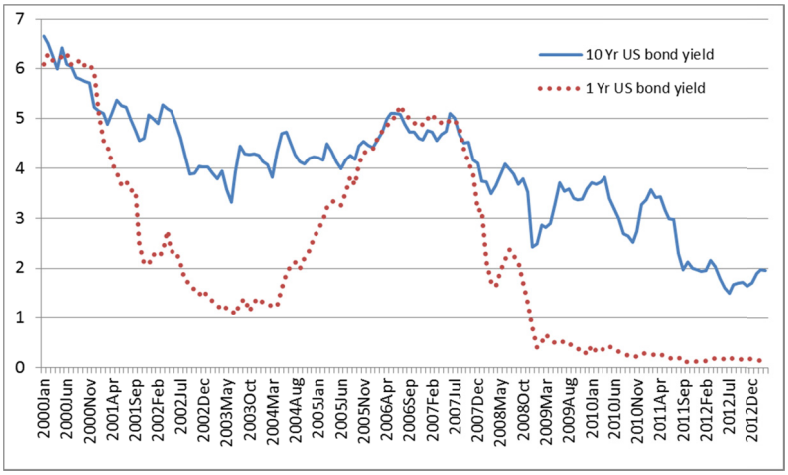
forward by Borio and Disyatat (2011), Shin (2011) and Laibson and Mollerstrom (2013). Yet these focus on a single decade during which the actual decline in long yields was comparatively moderate and so they do not discount the saving glut story as a driver of the longer term decline since the 1980s (Arora et al., 2014).

Relative to this comparatively smooth trend, the short yields in Figure 4 clearly show the two large US cycles that preceded the GFC and the tightening that led up to it in 2004–5, when petroleum prices rose (Note 8). It was this tightening that exposed those investors and financial institutions who expected short rates to remain low, precipitating the GFC. Beyond 2008, of course, the US (along with the UK and Japan) had driven its short yields near zero, exhausting all further scope for conventional monetary policy. Importantly, and this is clear from the more recent data on yields represented in Figure 5, the downward trend in long yields persists beyond the GFC in the US, the EU and Japan. Yet the evidence is building that the Asian savings glut is over, led by declining net saving in both Japan and China (Arora et al., 2014). What, then, explains the subsequent and continuing decline in long yields?

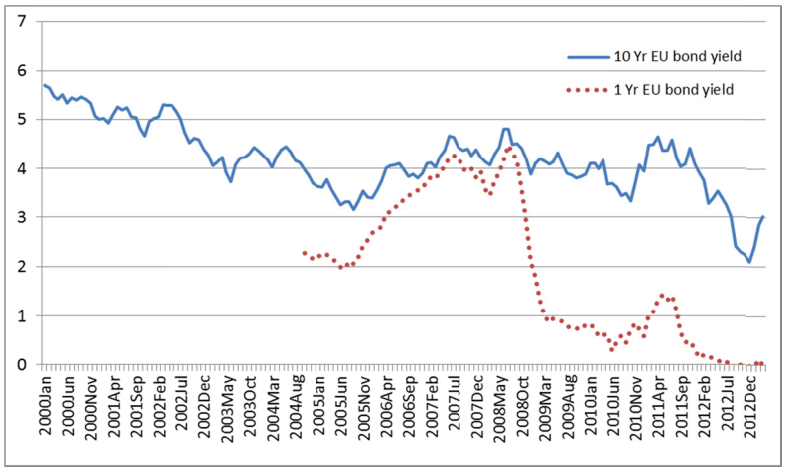
2.2 Unconventional Monetary Policy

Commonly referred to as "quantitative easing" (QE), this constitutes central banks' achievement of money expansions via the large scale purchase of longer maturity instruments, including long term treasury bonds. Considering that the big three economies have all been very slow growing since the GFC, it is notable that this has led to the substantial expansions in central bank asset holdings shown in Figure 6 (Note 9). These raise the prices of long bonds and related instruments and suppress their yields. Unlike more conventional monetary policy, the QE focus on instruments that arbitrage closely with longer maturity assets that are widely traded internationally projects the domestic monetary cycle beyond national borders with immediacy. In part for this reason, there is a tendency to see this policy matched across the three large advanced economies, causing financial flows into the "economies in transition", including China, as investors seek out better yields abroad (He & McCauley, 2014) (Note 10). Indeed, Chen et al. (2014) show that the resulting spill-overs have been large, affecting yields, equity prices, exchange rates and endogenous monetary responses in the "economies in transition".

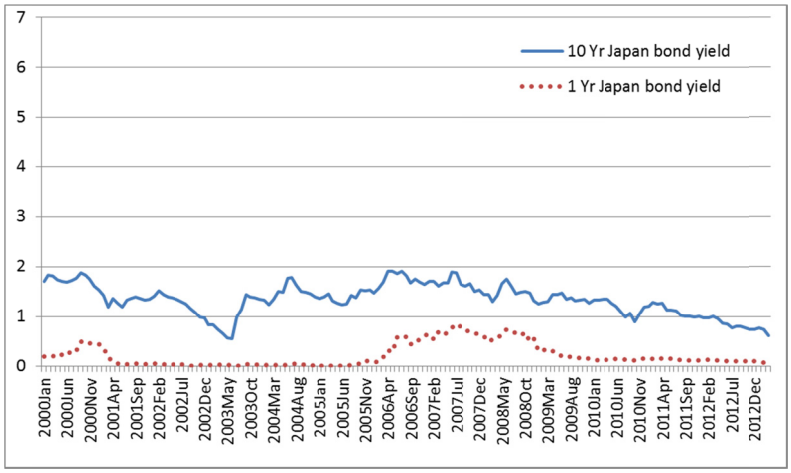
The reasons for these historic and partially unconventional monetary expansions are central to the analysis which follows in this paper. The three large incumbent economic regions each have, by their own historical standards, high unemployment. They also have historically high sovereign debt overhangs. To address the unemployment in the short run, further fiscal expansion therefore seems unwise, yet their liquidity traps prevent conventional monetary expansions. QE has offered an alternative stimulatory course, so long as private portfolio holders preoccupied with the risk of deflation are prepared to hoard at least part of the money thus supplied. Under these conditions, acquisitions by central banks offer the convenience of additional leeway for further government deficit spending. A widely unconsidered consequence, however, is that these unconventional central bank acquisitions have kept downward pressure on long yields and so tended to mask the recent decline in Asian excess saving.



Source: US Treasury.



Source: European Central Bank.



Source: European Central Bank, Reuters.

Figure 5. US, European and Japanese government bond yields since 2000

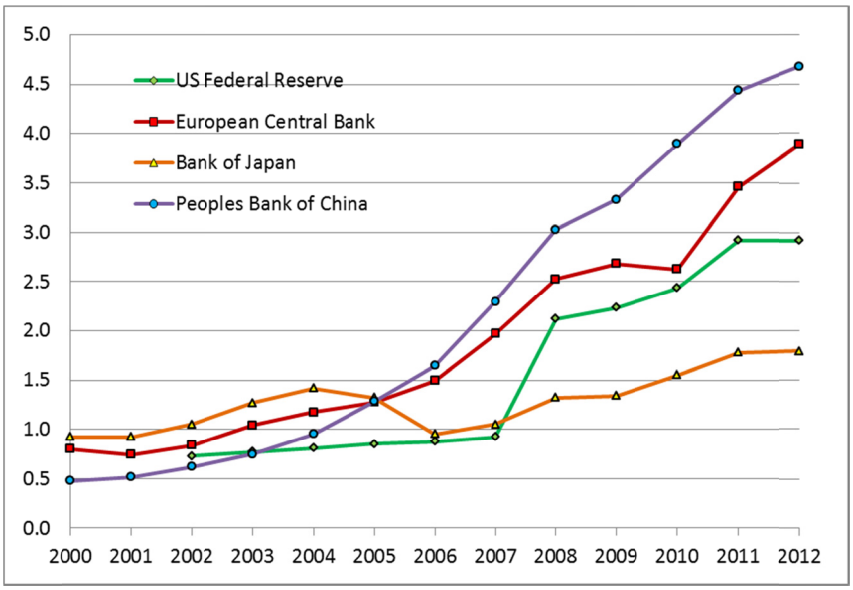


Figure 6. Central bank assets, US$ trillions

Sources: EU, ECB; United States, Japan: St. Louis Federal Reserve Database; China, National Bureau of Statistics.

2.3 The Global Game

Unconventional monetary policy is, for the present, a key instrument in a strategic game within the small club comprising the three incumbent, advanced regions, now joined by China. A substantial monetary expansion by one region tends to require a matching response from the others to avoid appreciations that would reduce competitiveness. In China, the other transitional economies and the resource exporting economies like Canada and Australia, outside the club, the result of aggressive monetary policy in the large advanced regions has been accelerating inflation, or more substantial nominal appreciations relative to the US (Note 11). Taylor (2013) laments the resulting departure from the stable, "rule-like" pre-GFC monetary policies, resulting in what he refers to as the "global great deviation". Further such uncoordinated responses of central banks could be destabilising, suggesting the need for more active official coordination. Engel (2014) takes up this theme, noting that the major determinants of nominal exchange rates in the past decade have been monetary policy and expectations over it, rather than the more commonly analysed supply side shocks.

Recent movements in the major currencies since 2000, shown in Figure 7, show that the US$ has gradually depreciated against all. Beyond that, the Yen, the Euro and the Yuan have tended to move together, particularly in the aftermath of the GFC, when they appeared to stabilise around their 2000 relativities, albeit all appreciating by a third against the US$. Very recently, there has been a break from this pattern with Japan's "Abenomics first arrow", requiring more aggressive QE and causing a substantial depreciation relative to the others. By contrast with previous decades, this depreciation has been tolerated by the other advanced economies. The US has pressured Japan less over its exchange rate since the turn of the century, which is due in part to its recent stagnation, the rise of China and the fact that Japan is now the smallest of the big four economic regions, so policy deviations by it are less costly to the others (Taylor, 2006). All this suggests a "coordination game" structure for the rewards from macro expansion policies within the large economy club. The analysis to follow investigates this in the context of an elemental model of the global economy.

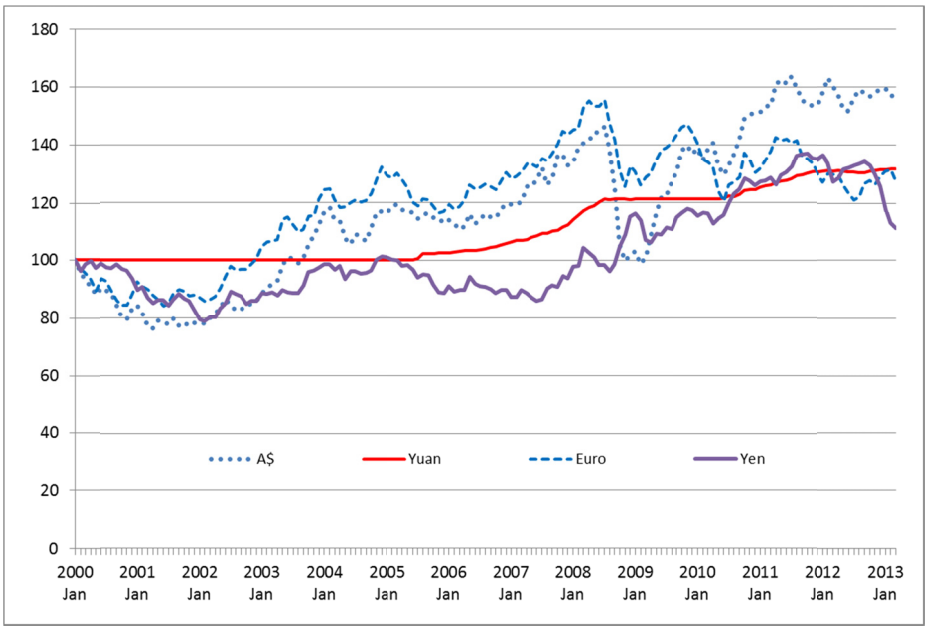


Figure 7. Nominal exchange rate indices vs the US$

Source: IMF IFS and Eurostat.

3. Modelling Macroeconomic Interdependence

The analysis addresses short run departures from the underlying long run growth path of the global economy. A multi-region general equilibrium structure is used that centres on the global financial capital market. Accordingly, it offers a new approach to modelling international financial flows in a deterministic setting. It is assumed that the financial products of each region are differentiated and that portfolio managers assign new net saving across regions so as to maximise expected portfolio returns given this differentiation. This approach retains Feldstein-Horioka (1980) home bias while allowing significant redirections in financial flows at the margin. It

also allows the level of global financial market integration to be parameterised by varying this degree of differentiation. The scale of spill-over effects associated with growth performance, excess saving and monetary policy therefore depend on it.

Although there is a tendency for financial flows to move the global economy toward interest parity, this differentiation prevents its achievement in the length of run considered. At the same time, regional rates of return on equity investments depart from regional bond yields, the former reflecting expected rates of return on installed capital and the latter short run equilibrium in regional financial markets between savers, indebted governments and investors. Global bond market integration ensures that yields in one region are affected by monetary policy in others, reflecting the high rate of monetary spill-over that is characteristic of modern "unconventional" monetary policy (Note 12).

Within each region the demand for money is driven by a "cash in advance" constraint applying across the whole of GDP. For any one household, home money is held in a portfolio with long maturity bonds, which are claims over physical capital across the regions and domestic government debt (Note 13). Six regions are identified: the US, the EU, Japan, China, Australia and the Rest of the World, though the focus of this paper is on the first four (Note 14). Each region supplies a single product that is also differentiated from the products of the other regions. On the supply side, there are three primary factors with "production" labour (L) a partially unemployed variable factor while the stocks of physical capital (K) and skill (S) are fixed and fully employed. Collective households are net savers with reduced form consumption depending on current and expected future disposable income and the home interest rate. Aggregate consumption is subdivided via a single CES structure between the products of all the regions. The more routine details of the model are provided in Appendix A.

3.1 Financial Markets

Here the modelling departs from convention by incorporating explicit portfolios of assets from all regions. Data on regional saving and investment for 2011 is first combined with that on international financial flows to construct an initial matrix to allocate total domestic saving in each region to investment across all the regions. From this is derived a corresponding matrix of initial shares of region i's net (private and government) saving that are allocated to the local savings supply that finances investment in region j, i_{ij}^{S0}. When the model is shocked, the new shares are calculated so as to favour investment in regions, j, with comparatively high after tax yields, generally implying high expected real gross rates of return, r^{ce}. This is calculated as:

$$r_i^{ce} = r_i^c + \hat{e}_i^e = \frac{P_i^P MP_i^K}{P_i^K}\left(\frac{\varphi_i^0}{\varphi_i}\right) + \hat{e}_i^e \tag{1}$$

where P_i^K is the price of capital goods, which in this model are linked by an exogenous factor to P_i^P, the producer price of the region's generic good (Note 15). The (exogenous) expected proportional change in the real exchange rate is $\hat{e}_i^e$. A further adjustment is made using an interest premium factor, φ_i, that is defined relative to the US ($\varphi_{US} = 1$). This permits consideration of the effects of changes in sovereign risk in association with the fiscal balance. Increments to regional sovereign risk cause investments in those regions to be less attractive.

$$\varphi_i = \varphi_i^0\left[\left(\frac{G_i}{T_i}\Big/\frac{G_{US}}{T_{US}}\right)\right]^{\phi_i}, \quad \forall i \neq "US" \tag{2}$$

where ϕ_i is an elasticity indicating sensitivity to sovereign risk.

In region i, then, the demand for investment financing depends on the ratio of the expected rate of return on installed capital, r_i^{ce} and a domestic market clearing bond yield or financing rate, r_i.

$$\frac{I_i^D}{I_i^0} = \left(\frac{r_i^{ce}}{r_i}\right)^{\varepsilon_i^I} \tag{3}$$

where ε_i^I is a positive elasticity enabling the relationship to reflect Tobin's Q-like behaviour. This investment demand is then matched in each region by a supply of saving that incorporates contributions from all regional households.

Region i's portfolio manager allocates the proportion i_{ij}^S of its annual (private plus government) saving to new investments in regions j, such that $\sum_j i_{ij}^S = 1$ (Note 16). Because the newly issued equity is differentiated across

regions based on un-modelled and unobserved region-specific properties, their services are combined via a constant elasticity of substitution (CES) function specific to each regional portfolio manager. Thus, region *i*'s household portfolio management problem is to choose the shares, i_{ij}^S , of its private saving net of any government deficit, $S_i^D = S_i^P + T^D + T^I - G$, which are to be allocated to the assets of region *j* so as to maximise a CES composite representing the value of the services yielded by these assets:

$$\max_{i_{ij}^S} U_i^F = S_i^D \left[\sum_j \alpha_{ij} (i_{ij}^S)^{-\rho_i} \right]^{-\frac{1}{\rho_i}} \quad \text{such that} \sum_j i_{ij}^S = 1 \tag{4}$$

Here α_{ij} is a parameter that indicates the benefit to flow from region *i*'s investment in region *j*. The CES parameter, ρ_i, reflects the preparedness of region *i*'s household to substitute between the assets it holds. To induce rebalancing in response to changes in rates of return the α_{ij} are made dependent on ratios of after-tax yields in destination regions, *j*, and the home region, *i*, via (Note 17):

$$\alpha_{ij} = \beta_{ij} \left(\frac{r_j / \tau_j^K}{r_i / \tau_i^K} \right)^{\lambda_i} \quad \forall i, j, \quad \lambda_i > 0 \quad \forall i \tag{5}$$

Here, τ_i^K is the power of the capita income tax rate in region *i*. This relationship indicates the responsiveness of portfolio preferences to yields, via the (return chasing) elasticity λ_i . The allocation problem, thus augmented, is:

$$\max_{i_{ij}^S} U_i^F = S_i^D \left[\sum_j \beta_{ij} \left(\frac{r_j / \tau_j^K}{r_i / \tau_i^K} \right)^{\lambda_i} (i_{ij}^S)^{-\rho_i} \right]^{-\frac{1}{\rho_i}} \quad \text{such that} \sum_j i_{ij}^S = 1 \tag{6}$$

Solving for the first order conditions we have, for region *i*'s investments in regions *j* and *k*:

$$\frac{i_{ij}^S}{i_{ik}^S} = \left(\frac{\beta_{ij}}{\beta_{ik}} \right)^{\frac{1}{1+\rho_i}} \left(\frac{r_j / \tau_j^K}{r_k / \tau_k^K} \right)^{\frac{\lambda_i}{1+\rho_i}} \tag{7}$$

This reveals that region *i*'s elasticity of substitution between the bonds of different regions is $\sigma_i^I = \lambda_i / (1+\rho_i) > 0$, which has two elements. The return-chasing behaviour of region *i*'s household (λ_i) and the imperfect substitutability of regional bonds, and therefore the sluggishness of portfolio rebalancing (ρ_i).

The optimal share of the net domestic saving of region *i* that is allocated to assets in region *j* then follows from (7) and the normalisation condition, that $\sum_k i_{ik}^S = 1$:

$$i_{ij}^S = \frac{1}{\sum_k \left(\frac{\beta_{ik}}{\beta_{ij}} \right)^{\frac{\sigma_i^I}{\lambda_i}} \left(\frac{r_k / \tau_k^K}{r_j / \tau_j^K} \right)^{\sigma_i^I}} \tag{8}$$

The key matrix for calibration is [β_{ij}]. These elements are readily available, first, by noting that only relative values are required and hence, for each region of origin, *i*, one value can be set to unity, and second, by making the assumption that the initial database has the steady state property that the net rates of return in regions *j* are initially the same as the market bond yield, r_j. Then, since in the base data $r_{ij}^{e0} = r_j^0$, $r_{ik}^{e0} = r_k^0$, the β_{ij} s are available from a modified (5):

To complete the financial market specification, investment demand in each region is equated with the global supply of saving to that region. Total investment spending in region *j*, in *j*'s local currency, is then:

$$I_j = I_j^D = \sum_i \left(i_{ij}^S S_i^D \frac{E_i}{E_j} \right), \quad \forall j \tag{9}$$

where E_i is the nominal exchange rate of region *i* relative to the US$, which is the numeraire in the model

($E_{US}=1$). The regional real bond yields (interest rates, r_j) emerge from this equality. Their convergence across regions is larger the larger are the elasticities of asset substitution, σ_j^I.

3.2 Regional Money Market Equilibrium

A cash-in-advance constraint is assumed to generate transactions demand for home money across all components of GDP. The opportunity cost of holding home money is set at the nominal after-tax yield on home long term bonds. Real money balances are measured in terms of purchasing power over home products.

$$m_i^D = a_i^{MD} \left(y_i\right)^{\varepsilon_i^{MY}} \left(\frac{r_i + \pi_i^{Ye}}{\tau_i^K}\right)^{-\varepsilon_i^{MR}} = \frac{M_i^S}{P_i^Y} \tag{10}$$

Here y is real regional GDP, P^Y is the GDP price and π_i^{Ye} is the expected inflation rate of the GDP price level, P^Y, which is defined in Appendix 1. The nominal money supply, M^S, can be set as an exogenous policy variable or endogenous to a price level or exchange rate target.

3.3 The Database and Parameters

The model database is built on national accounts, international trade and financial data for the global economy in 2011. The relative sizes of the four major economic regions, the US, the EU, Japan and China are indicated in Table 1, from which it is clear that China's economy (even measured without PPP adjustment) is not the smallest of them and it matches the largest in investment, exports and saving.

Table 1. Relative economic sizes of China and the other large regions, ca 2011

% of world	China	US	EU(26)	Japan
GDP	11	22	26	9
Consumption, *C*	8	27	26	9
Investment, *I*	20	15	22	8
Government spending, *G*	7	20	30	10
Exports, *X*	17	17	25	7
Imports, *M*	15	21	23	8
Total domestic saving, S^D	19	13	20	9

Sources: National accounts data supply most of the elements though adjustments have been required to ensure that current accounts sum to zero globally, as do capital/financial accounts. The IMF-IFS database is the major source but there is frequent resort to national statistical databases.

Table 2. Regional economic structure, 2011

% of GDP	US	EU(26)	Japan	China	Australia	RoW
C	0.712	0.580	0.605	0.450	0.536	0.550
I	0.155	0.191	0.200	0.410	0.275	0.240
G	0.171	0.217	0.204	0.114	0.177	0.199
X	0.139	0.175	0.151	0.285	0.217	0.200
M	0.177	0.163	0.161	0.259	0.204	0.189
Indirect tax rev, T^I	0.144	0.235	0.047	0.125	0.070	0.130
Direct tax rev, T^D	0.017	0.015	0.124	0.035	0.093	0.061
Total tax rev, *T*	0.161	0.250	0.171	0.160	0.163	0.191
Private saving, S^P	0.127	0.169	0.224	0.390	0.301	0.259
Govt saving, S^G	-0.010	0.034	-0.034	0.046	-0.013	-0.008
Total saving, S^D	0.155	0.191	0.200	0.410	0.275	0.240
Monetary base, M^B	0.133	0.114	0.220	0.411	0.134	0.250
Capital stock, *K*	3.317	3.414	4.239	2.740	4.027	2.000

Sources: National accounts data supply most of the elements though adjustments have been required to ensure that current accounts sum to zero globally, as do capital/financial accounts. The IMF-IFS database is the major source but there is frequent resort to national statistical databases.

The structures of the regional economies are indicated in Table 2. They differ in important ways. The US has a high consumption share of GDP, China a low one. Necessarily, then, the US has a low saving share while China

has a high one. Some regions are more dependent on indirect taxes than others, which makes a difference to the proportion of GDP made up of factor cost and hence the size of the household budget and the gap between producer and GDP prices. The EU is relatively dependent on indirect taxes, for example.

Since these taxes (at least those accounted for in the model) fall most heavily on consumption, changes in saving behaviour have strong implications for fiscal deficits and, indirectly, for interest premia. Investment is larger in some than in others, being extraordinarily high in China. And then, of course there are the fiscal deficits that are largest in the US and Japan, and the current account surpluses or capital-financial account deficits in Japan and China, at least partly funding the very substantial deficit in the US.

Interactions between these large economies through trade are captured in the consumption expenditure matrix shown in Table 3. It is derived from the combination of national accounts with a matrix of trade flows. The flows are expenditures inclusive of indirect taxes, converted into the shares of total expenditure on goods and services by each country. Implicit, and consistent with the one-good per region model, is the assumption that investment and government spending make demands on the markets for home goods only. As it turns out, this assumption has important implications for the representation of China in the model. Since its consumption is comparatively low and its investment high, home products are mostly absorbed by investment and government spending and so China's consumption is distributed more evenly across regional goods than for the other economies. This suggests a case for an import-dependent capital goods industry in the model.

Table 3. Shares of consumption by region of origin, 2011[a]

% of row consn expenditure	US	EU(26)	Japan	China	Australia	RoW
US	65.9	10.3	2.3	6.1	0.5	14.9
EU(26)	12.0	43.9	2.9	11.2	0.6	29.4
Japan	4.7	5.1	69.1	6.5	2.3	12.3
China	10.4	18.2	11.2	17.6	4.5	38.1
Australia	8.1	12.8	3.8	9.2	53.7	12.5
Rest of world	14.4	22.0	3.9	10.6	1.0	48.1

Note. a These shares sum to 100 horizontally. They are based on the 2011 matrix of trade flows combined with consumption expenditure data in each region. The resulting matrix is inconsistent as between data sources and so a RAS algorithm is used to force consistency of bilateral elements with national accounts data.

Sources: Implied trade flows are for 2011, drawn from the World Trade Organisation database.

Table 4. Shares of total domestic saving directed to investment in each region, 2011[a]

% of row total saving	US	EU(26)	Japan	China	Australia	RoW
US[b]	68.0	13.3	6.4	6.4	1.5	4.4
EU(26)[c]	12.9	80.1	2.3	2.3	0.9	1.5
Japan[d]	14.0	3.3	72.2	6.2	0.7	3.6
China[c]	9.2	0.6	0.9	81.1	0.1	8.0
Australia[e]	13.0	4.8	2.3	2.1	77.3	0.4
Rest of world	3.4	3.9	2.6	2.8	0.1	87.2

Note. a These shares sum to 100 horizontally. They are based on 2011 investment flows. Elements are adjusted so that row and column sums are consistent with other data. The row sums of the flow matrix are total saving by region and the column sums are total investment by region. These sums are sourced from the IMF-IFS database and the World Bank database.

b USA: values are based on official statistics, BEA.

c EU and China: indirect information from USA, Australian and Japanese statistics.

d Japan: estimated based on FDI data, assuming investment outflow=FDI*1.6. The ratio 1.6 is that of USA reported inward investment from Japan divided by Japanese reported outward FDI to the USA.

e Australia: Australian Bureau of Statistics "International Investment Position, Australia: Supplementary Statistics, 2011".

f ROW is a residual. Its saving is inferred from national accounts estimates and its investment abroad is determined to balance the matrix of financial flows.

The financial interactions between the regions are indicated by the saving-to-investment flows in Table 4. These

show the expected Feldstein-Horioka (1980) behaviour but also that there are substantial financial interactions between the US, the EU and Japan in particular. The share of excess saving directed to the US might be expected to change due to the recent decline in reserve accumulation by China and its substitution with outward FDI that, most recently, has not been directed to the US (Tyers et al., 2013).

4. Pessimism Shocks, Monetary Policy and Strategic Interaction

Comparative static analysis using the model requires that a set of shocks be applied to exogenous policy variables or behavioural parameters. These "levers" are listed in Table 5 (Note 19). Associated closure choices available in the model are listed in Table 6.

Table 5. Exogenous variables for experimentation

Policy	Instrument	
Tax rates	Labour income tax	t_L
	Capital income tax	t_K
	Consumption tax (GST)	t_C
	Import tariff	t_M
	Export tax	t_X
Fiscal policy	Government spending, *US$ trillion*	G
	fiscal surplus, *US$ trillion*	S_G
Monetary policy	Monetary base, *US$ trillion*	M_B
	Reserve to deposit ratio	ρ
Expectations over future values	Consumer price inflation rate	π^{Ce}
	GDP price inflation rate	π^{Ye}
	Real exchange rate appreciation	$\hat{e}^e$
	Nominal disposable income	$Y_D{}^e$
	Rate of return on installed capital	$r_C{}^e$
Productivity	TFP	A^Y
Saving	Consumption preference shifter	A^C

Central banks in the US, Europe and Japan have found themselves in liquidity traps (effectively zero yields on short term money market instruments) because, for reasons discussed earlier, private agents have anticipated deflation and hence "hoarded" money (the share of global portfolios held as money greatly increased after 2008, more than doubling in the US alone). For this application, imagine that the US, EU and Japan are in liquidity traps and hence cannot use conventional monetary policy to further target their price levels.

Table 6. Closure choices and policy regimes

	In each case, holding fixed or exogenous one of:	
Labour market	Nominal wage	W
	Labour use	L
Government	Nominal expenditure	G
	Fiscal surplus	S_G=T-G
Monetary target	Monetary base	M_B
	Consumer price level	P^C
	GDP price level	P^Y
	Producer price level	P^P
	Exchange rate	E

Their economies are subjected to a set of pessimism shocks. Deflation, by five per cent, is expected in the GDP price, π^{Ye}, which induces money hoarding via (10), and in the consumer price, π^{Ce}, which affects consumption via (A6). The money hoarding raises the price of money relative to goods and hence brings the expectation to fruition. This is exacerbated in the experiment by the addition of other pessimism shocks, including an expected 10 per cent decline in nominal disposable income, Y^{De}, which also affects consumption via (A6) and a two per cent decline in the net rate of return on installed capital, r_C^e, which affects investment via (3). For these pessimism shocks, the closures required and the detailed shock statements are listed in software format in

Appendix B.

4.1 Pessimism Shocks Only

As indicated in the summary provided in Table 7, the resulting deflation is shared roughly equally across the three large advanced economies and it is transmitted at slightly lower rates to the regions maintaining fixed nominal exchange rates with the US, China and the Rest of the World. While Australia's monetary target is the producer price level, changes in the distribution of consumption across home and imported products that are associated with its real appreciation cheapen consumer goods slightly. The pessimistic regions suffer real depreciations against the others, as expected, though that of the US is by far the largest. This is because the associated financial outflows are proportionally larger from the US and so the US current account deficit falls by more. The contraction in aggregate demand in the pessimistic regions causes substantial reductions in their own and in global economic activity and employment. Their collective households are unambiguously worse off as a consequence. Because other regions benefit from an increase in investment expenditure, as portfolios rebalance out of the pessimistic regions' assets, and hence their real exchange rates appreciate, they enjoy a favourable shift in their terms of trade. This raises net welfare in both China and Australia slightly.

Table 7. Pessimistic expectations in liquidity trapped US, EU and Japan: simulation results[a]

% change	US	EU(26)	Japan	China	Australia	RoW
US, EU, Japan liquidity trap (M_B fixed)						
Monetary base, M_B	0.0[b]	0.0[b]	0.0[b]	-1.1	0.2	-1.9
Prices and exchange rates						
Consumer price level, P^C	-1.9	-2.3	-2.5	-1.1	-0.2	-1.1
Producer price level, P^P	-2.4	-2.1	-2.5	-0.7	0.0[b]	-0.9
GDP price level, P^Y	-2.8	-2.8	-2.6	-0.6	0.0	-0.8
Nominal exch rate v US, E	0.0	1.3	1.4	0.0[b]	-0.6	0.0[b]
Real exch rate v US, e	0.0	1.3	1.6	2.3	2.3	2.1
Interest rates						
Real bond yield, r	-0.8	-0.7	-0.4	0.4	-0.3	1.3
Nominal bond yield, $r+\pi^{Ye}$	-5.7	-5.7	-5.4	0.4	-0.3	1.3
Balance of payments						
Change in CA, %GDP	1.1	0.3	0.3	-1.0	-0.6	-0.8
Real volumes						
Real consumption, c	-4.1	-3.4	-2.8	1.0	0.6	0.8
Real investment, I/P^P	0.6	0.4	0.9	1.2	1.5	0.5
Labour use, L	-2.9	-2.6	-3.1	-1.0	0.0[c]	-1.2
Real GDP, $y=Y/P^Y$	-0.5	-0.5	-0.6	-0.3	0.0[c]	-0.3
Purchasing power of income at consumer prices						
Welfare, Y/P^C	-1.5	-1.0	-0.7	0.2	0.3	0.0

Note. a These results are generated by the Gempack-Rungem software from the closures and shocks listed in Appendix 2.

b These are targets of monetary policy.

c These are the direct consequences of targeting *producer* price levels.

4.2 The Monetary Policy Offset in the US, EU and Japan

The second simulation imagines that the same pessimistic shocks occur but the power of conventional monetary policy is not exhausted (there is a transition to unconventional monetary policy that allows continued expansions in liquidity). This allows the central banks of all three pessimistic regions to target their producer prices and thereby hold employment and real GDP constant. The rise in liquidity required to achieve this, however, is massive, as suggested by the results presented in Table 8. These large annual monetary expansions then demand similarly large expansions by the fixed parity regions, China and the Rest of the World. Even Australia must undertake a considerable monetary expansion as money demand rises with the dramatic world-wide fall in interest rates. Essentially, by sustaining their employment through liquidity expansion, the pessimistic regions keep up their saving levels, but these savings are largely directed abroad due to the pessimism of their collective households. Current account balances therefore tend to shift toward surplus in the pessimistic regions and toward deficit in the others, with very large inflows going into China and Australia and large increases in investment

there. This raises formal sector employment and real GDP in the parity regions, China and the Rest of the World. They and Australia have large real appreciations that also engender improvements in their terms of trade. This dominates the welfare bottom line, which sees the pessimistic regions worse off and the others considerably better off (Note 18).

Table 8. Pessimistic expectations in the US, EU and Japan with activist monetary policy: simulation results[a]

% change	US	EU(26)	Japan	China	Australia	RoW
Effective monetary policy in US, EU and Japan, targeting producer price levels						
Monetary base, M_B	10.7	10.2	11.8	16.5	7.1	12.7
Prices and exchange rates						
Consumer price level, P^C	1.4	-0.5	2.1	3.8	-5.0	3.6
Producer price level, P^P	0.0[b]	0.0[b]	0.0[b]	6.3	0.0[b]	4.1
GDP price level, P^Y	-0.7	-0.8	-0.3	6.0	0.8	3.8
Nominal exch rate v US, E	0.0	4.4	-2.3	0.0[b]	15.1	0.0[b]
Real exch rate v US, e	0.0	4.3	-1.9	6.8	16.9	4.6
Interest rates						
Real bond yield, r	-14.9	-14.1	-16.0	-12.7	-10.5	-12.3
Nominal bond yield, $r+\pi^{Ye}$	-19.2	-18.4	-20.2	-12.7	-10.5	-12.3
Balance of payments						
Change in CA, %GDP	2.2	-0.1	3.0	-2.5	-9.0	-0.9
Real volumes						
Real consumption, c	-5.9	-2.9	-6.0	2.3	15.1	-0.3
Real investment, I/P^P	2.4	7.2	-4.8	12.6	13.8	12.8
Labour use, L	0.0[c]	0.0[c]	0.0[c]	8.7	0.0[c]	5.4
Real GDP, $y=Y/P^Y$	0.0[c]	0.0[c]	0.0[c]	2.2	0.0[c]	1.2
Purchasing power of income at consumer prices						
Welfare, Y/P^C	-2.1	-0.2	-2.3	4.5	6.1	1.5

Note. a These results are generated by the Gempack-Rungem software from the closures and shocks listed in Appendix 2.

b These are targets of monetary policy.

c These are the direct consequences of targeting *producer* price levels.

4.3 Monetary Response in Only the US

To gauge the extent of strategic interaction between the large economies it is useful to simulate the pessimism shocks with a monetary response (the resort to unconventional monetary policy) only in the US. The results for this case are presented in Table 9. The monetary expansion required for the US to restore full employment only in its domestic economy is smaller than what would be required in concert with the EU and Japan. Yet this expansion depresses US interest rates by considerably more than those in the EU and Japan. This directs US saving, which is boosted by the full employment achieved by its monetary expansion, out to the EU and Japan. The resulting financial flows see a contracting US current account (CA) deficit while the current accounts of the EU and Japan shift substantially toward deficit.

Table 9. Pessimistic expectations in the US, EU and Japan with active monetary policy only in the US[a]

% change	US	EU(26)	Japan	China	Australia	RoW
Effective monetary policy in the US only, targeting the producer price level						
Monetary base, M_B	5.8	0.0	0.0	10.7	2.4	9.9
Prices and exchange rates						
Consumer price level, P^C	2.3	-8.2	-6.4	6.4	-1.7	5.6
Producer price level, P^P	0.0[b]	-4.5	-4.3	5.3	0.0[b]	4.3
GDP price level, P^Y	-1.0	-3.5	-4.2	4.6	0.3	3.7
Nominal exch rate v US, E	0.0	16.7	17.9	0.0[b]	10.3	0.0[b]
Real exch rate v US, e	0.0	13.8	14.1	5.7	11.7	4.8
Interest rates						

Real bond yield, r	-6.7	-2.8	-4.0	-6.7	-3.6	-7.8
Nominal bond yield, $r+\pi^{Ye}$	-11.4	-7.6	-8.8	-6.7	-3.6	-7.8
Balance of payments						
Change in *CA*, %GDP	3.7	-3.8	-3.6	1.1	-3.4	1.4
Real volumes						
Real consumption, c	-8.4	6.7	2.4	-4.3	4.8	-3.9
Real investment, I/P^I	-1.8	5.5	6.1	5.6	5.4	7.2
Labour use, L	0.0[c]	-5.4	-5.2	7.3	0.0[c]	5.7
Real GDP, $y=Y/P^Y$	0.0[c]	-1.0	-0.9	1.9	0.0[c]	1.3
Purchasing power of income at consumer prices						
Welfare, Y/P^C	-3.3	4.1	1.4	0.2	2.0	-0.5

Note. a These results are generated by the Gempack-Rungem software from the closures and shocks listed in Appendix 2.

b These are targets of monetary policy.

c These are the direct consequences of targeting *producer* price levels.

This causes considerable US nominal and real depreciations that are largest against the EU and Japan. On the one hand, this means that the EU and Japan enjoy large improvements in their terms of trade, which enhances their welfare, but on the other, the levels of deflation in their economies are enlarged by the US action. This causes larger contractions in employment and GDP than would have occurred without the US action.

Given that the high social costs of unemployment the outcome for the EU and Japan is clearly inferior to both the case with no monetary responses and the case in which all three pessimistic regions move to unconventional monetary policy. The strategic interaction between these economies therefore has a coordination element under which equilibria require either coordinated inaction or coordinated responses. Evidence that this coordination, suggested by uniformly active monetary policy in the three large regions, is other than merely induced by first movers motivated by domestic criteria only, is weak (Ostry 2014). Active coordination is constrained in reality by uncertainty and disagreements over the effects of monetary policy and by asymmetries in country size and the scale of spill-overs.

5. Conclusion

The global macroeconomic game between the four largest economies is reviewed, showing its strategic nature, particularly since the graduation of China. A model is proposed for capturing the short run elements of this game. The model has conventional structure, though it embodies complete bilateral matrices of both trade and investment flows and a variety of direct and indirect tax instruments. It is applied comparative statically.

The model is illustrated with an application to pessimistic (deflationary) expectations and monetary policy responses in the US, the EU and Japan. The scenario considered has portfolio holders anticipating disposable income declines and continued deflation in the US, the EU and Japan, and their central banks are hamstrung by liquidity traps and so are effectively targeting the money supply. The pessimism then gives rise to the deflation that it anticipates and there are substantial negative real effects in all three regions. If, on the other hand, the central banks of the pessimistic regions are able to undertake further monetary expansion via unconventional means their levels of employment and real GDP can be restored. The pessimism nonetheless drives considerable financial outflows that see other regions enjoy rising investment and employment and improvements in their terms of trade.

If, however, only the US offers a monetary response to the pessimism shocks then the implications for the EU and Japan are inferior to those when no region is able to respond or when all regions respond. This suggests elements of coordination game structure amongst the big four economies in which equilibria are characterised by either collective action or inaction. Increasingly, the advent of China in this group will ensure that coordination pressures extend to Chinese government policy.

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Notes

Note 1. See Bernanke (2005), Chinn and Ito (2007), Choi et al. (2008) and Ito (2009), Arora et al. (2014).

Note 2. This consequence is the focus of the extensive literature on international policy coordination. Classic and recent contributions include those by Corden (1985), Mundell (1997), Eichengreen (2013) and Taylor (2013).

Note 3. For a discussion of the transition to inward-focussed growth see Tyers (2014).

Note 4. This is the focus of recent papers by Tyers et al. (2013) and Arora et al. (2014).

Note 5. While this is true as a rule of thumb, housing investment can be sensitive to short rates in economies where most mortgage contracts have variable rates. The assumption that investment financing depends on the long maturity market is accurate in a comparative sense and it is a useful abstraction.

Note 6. This is akin to the shift in the centre of gravity of the global economy toward Asia, from coordination via the G7 to the G20 (Klein and Salvatore 2013).

Note 7. This long run pattern is also observable in the long yields of the other advanced economies (Arora et al.,

2014).

Note 8. Its origins in petroleum markets are analyzed by Arora and Tyers (2011).

Note 9. It is notable that China's monetary base is large compared with the others, which is likely due to reduced money creation by China's commercial banks in response to such restrictions as high reserve to deposit ratios.

Note 10. Of course, one clear rationale for QE on the part of the US Federal Reserve is that the substitution will be away from US bonds to US equities. And this has happened too. Much less is said by the Fed about the international effects.

Note 11. The Australian dollar, for example, is the resource currency of an outsider economy that is not a default risk and that has not engaged in aggressive monetary expansion. Return-seeking financial flows from the QE economies have therefore boosted its value in the post-GFC period.

Note 12. A high degree of long bond market integration, at least across advanced economies, is established by Arora et al. (2014).

Note 13. Expectations are exogenous in the model and are formed over future values of home nominal disposable income, the rate of inflation, the real rate of return on home assets and bilateral real exchange rate alignment.

Note 14. The EU is modeled as the full 26 and it is assumed that this collective has a single central bank.

Note 15. The producer price level is the factory door price of the regional good, which differs in this model from the GDP price level due to indirect taxation. See Appendix 1 for an explanation of this.

Note 16. The manager does not re-optimise over *total* holdings every year. This is because the model is deterministic and risk is incorporated only via exogenous premia, so the motivations for continuous short run rebalancing, other than the arrival of new saving, are not represented.

Note 17. Note that region *i*'s market bond yield, r_i, is determined concurrently and indicates the replacement cost of capital in region *i* and therefore the opportunity cost for region *i*'s household of investment in region *j*.

Note 18. This pattern reflects observed changes in the global economy in the post-GFC period and it helps to explain the role of financial outflows from the large advanced economies in the persistence of Australia's high real exchange rate despite moderation in its terms of trade. The opposite of these shocks are also feasible, however, as the US and Japanese economies recover and pessimism recedes there. These results suggest such changes will be unambiguously bad for Australian welfare.

Note 19. Multiple shocks can be applied simultaneously, though it should be recalled that the further from the initial equilibrium the software is forced to look for a solution the more difficult it is to find one and the less accurate is the solution obtained.

Note 20. US currency is the numeraire in the model.

Note 21. In the model database, direct transfers are netted from direct tax revenue, so that *T*-*G* is the true fiscal surplus.

Appendix A

Model Analytics–The Conventional Components and Parameters

Key financial relationships are given in the main text. This appendix lists the more standard details of the model's specification.

Output is assumed to be Cobb-Douglas in the three primary factors, so that, for regions *i,* local output and the marginal product of capital are:

$$y_i = A_i^Y L_i^{\beta_i^L} S_i^{\beta_i^S} K_i^{\beta_i^K}, \quad MP_i^K = \beta_i^K \frac{y_i}{K_i} = \left[A_i^Y \beta_i^K S_i^{\beta_i^S} K_i^{\beta_i^K - 1} \right] L_i^{\beta_L}, \quad \beta_i^L + \beta_i^S + \beta_i^K = 1 \,\forall i \tag{A1}$$

The real volume of output, y, is distinguished from nominal GDP, $Y = P^Y y$, where P^Y is the *GDP price* level (deflator). The real production wages of unskilled and skilled workers depend conventionally on the corresponding marginal products.

$$w_i = \frac{W_i}{P_i^P} = \beta_i^L \frac{y_i}{L_i}, \quad w_i^S = \frac{W_i^S}{P_i^P} = \beta_i^S \frac{y_i}{S_i} \tag{A2}$$

Here the upper case wages are nominal and the lower case real and P^P is the *producer* price level.

Both direct and indirect tax revenues, T^D and T^I, play key roles in the formulation. GDP at factor cost (or producer prices), Y^{FC}, is the total of direct payments to the collective household in return for the use of its factors. Region *i*'s nominal GDP is then

$$Y_i = Y_i^{FC} + T_i^I, \quad Y_i^{FC} = C_i + T_i^D + S_i^P \tag{A3}$$

This is the standard disposal identity for GDP, or the collective household budget, where *C* is the total value of final consumption expenditure, including indirect taxes paid, and S^P is private saving. The GDP price, P^Y, and the producer price, P^P, would be the same were it not for indirect taxes. In their presence we have:

$$Y_i = P_i^Y y_i = P_i^P y_i + T_i^I \text{, so that } P_i^Y = P_i^P + \frac{T_i^I}{y_i} \tag{A4}$$

A1. Direct Tax

Constant marginal direct tax rates, t^W and t^K, apply to all labour and capital income. The corresponding "powers" of these rates are $\tau^L = \left(1 + t^L\right)$ and $\tau^K = \left(1 + t^K\right)$ and total direct tax revenue is:

$$T_i^D = t_i^L \left(W_i L_k + W_i^S S_i\right) + t_i^K P_i^P M P_i^K K_i \tag{A5}$$

Indirect tax revenue, T^I, depends on consumption and trade and so it will emerge later.

A2. Consumption

Aggregate consumption expenditure, *C*, is a nominal sum but real consumption behaviour is motivated by real incomes and the real interest rate. Real consumption, (lower case) *c*, depends negatively on the real after-tax return on savings (the home bond yield, *r*) and positively on both current and expected future real disposable income:

$$c_i = \frac{C_i}{P_i^C} = A_i^C \left(\frac{r_i}{\tau_i^K}\right)^{-\varepsilon_i^{CR}} \left(\frac{Y_i^D}{P_i^C}\right)^{\varepsilon_i^{CY}} \left(\frac{Y_i^{De}}{P_i^C\left[1 + \pi_i^{Ce}\right]}\right)^{\varepsilon_i^{CY}} \tag{A6}$$

where the expected inflation rate of the consumer price level is π^{Ce}. To capture the home household's substitution between home and foreign products, real aggregate consumption in region *i* is a CES composite of region *i*'s consumption of products from all regions:

$$c_i = \left(\sum_j \alpha_{ij} c_{ij}^{-\theta_i}\right)^{-\frac{1}{\theta_i}} \tag{A7}$$

The home household then chooses its mix of consumed products to minimise consumption expenditure in a way that accounts for home indirect tax rates, foreign export taxes and differing foreign product prices and exchange rates:

$$C_i = P_i^C c_i = P_i^P \tau_i^C c_{ii} + \sum_j \tau_i^C \tau_i^M \tau_j^X c_{ij} P_j^P \frac{E_j}{E_i} \tag{A8}$$

where τ_i^C, τ_i^M and τ_j^X are, respectively, the powers of region *i*'s consumption and import taxes and the region of origin, *j*'s export tax. E_i is region *i*'s nominal exchange rate, measured as US$ per unit of home currency (Note 20).

Optimum consumption is consistent with an elasticity of substitution between home and foreign products of $\sigma_i = 1/\left(1 + \theta_i\right)$. The Marshallian demands are then:

$$c_{ii} = \alpha_{ii}^{\sigma_i} \frac{C_i}{P_i^C}\left[\frac{P_i^P \tau_i^C}{P_i^C}\right]^{-\sigma_i}, \quad c_{ij} = \alpha_{ij}^{\sigma_i} \frac{C_i}{P_i^C}\left[\frac{\tau_i^C \tau_i^M P_j^P \left(E_j / E_i\right)}{P_i^C}\right]^{-\sigma_i}, i \neq j \tag{A9}$$

Given these consumption volumes, the composite price of all consumption, or the consumer price level, emerges from the substitution of (A7) and (A9) in (A8) as:

$$P_i^C = \tau_i^C \left[\alpha_{ii}^{\sigma_i} \left(P_i^P \right)^{1-\sigma_i} + \tau_i^M \sum_{j \neq i} \alpha_{ij}^{\sigma_i} \left\{ \frac{P_j^P E_j}{E_i} \right\}^{1-\sigma_i} \right]^{\frac{1}{1-\sigma_i}} \tag{A10}$$

A3. The Global Product Balance

Each region's product is differentiated from the others and so global product balance stems from a version of the expenditure identity in real volume terms:

$$y_i = \frac{I_i + G_i}{P_i^P} + \sum_j c_{ji} \tag{A11}$$

where the final term is the sum of real consumption and real exports. Neither investors nor the government pay indirect taxes on their expenditure and so the price they face for the home product is the producer price, P^P. This equation solves indirectly for the producer prices.

A4. Private Saving

Households receive income amounting to GDP at factor cost, Y^{FC}. Their disposable nominal income is this sum less direct tax (A5), and private saving is what remains after consumption expenditure (A8) is further deducted.

$$Y_i^D = P_i^P y_i - T_i^D, \; S_i^P = Y_i^D - C_i \tag{A12}$$

A5. Indirect Tax Revenue

This includes revenue from consumption, import and export taxes:

$$T_i^C = t_i^C \left(P_i^P c_{ii} + \sum_j \tau_i^M \tau_j^X c_{ij} P_j^P \frac{E_j}{E_i} \right) \tag{A13}$$

$$T_i^M = t_i^M M_i, \quad M_i = \sum_{j \neq i} \tau_j^X c_{ij} P_j^P \frac{E_j}{E_i} \tag{A14}$$

$$T_i^X = t_i^X X_i, \quad X_i = \sum_j c_{ji} P_i^P \tag{A15}$$

$$T_i^I = T_i^C + T_i^M + T_i^X, \quad T_i = T_i^D + T_i^I \tag{A16}$$

A6. Government and Total Domestic Saving

This is government revenue less government expenditure, both measured net of direct transfers. To simplify the demand side, spending by the government is assumed to be directed only at home goods (Note 21). It pays no taxes and so faces the home producer price P^P. Total domestic saving is then the sum of private and government savings in the home economy, in home currency.

$$S_i^D = S_i^P + S_i^G = S_i^P + T^D + T^I - G \tag{A17}$$

A7. Balance of Payments

The sum of net inflows of payments on the current account and net inflows on the capital and financial accounts, measured in a single (home) currency is zero:

$$X_i - M_i + \sum_{j \neq i} \left(i_{ji}^S S_j^D \frac{E_j}{E_i} \right) - \sum_{j \neq i} \left(i_{ij}^S S_i^D \right) = 0, \quad \forall i \neq "US" \tag{A18}$$

Balance in the US is implied by balance in all the other regions. These equations determine the nominal exchange rates and, since these are defined relative to the US$, that for the US is always unity $\left(E_{US} = 1 \right)$.

A8. Real Exchange Rate

Each region has a real exchange rate relative to the US that is the rate of exchange between regional product bundles. With the regions specified as single product economies this measure parallels the terms of trade. Both real and nominal exchange rates are expressed according to the financial convention, so that an appreciation is a rise in value.

$$e_i = \frac{P_i^Y}{\left(\frac{P_{US}^Y}{E_i}\right)} = E_i \frac{P_i^Y}{P_{US}^Y} \tag{A19}$$

A9. Parameters

Finally, a complete list of the behavioural parameters used in the model is provided in Table A1.

Table A1. Parameters

	US	EU(26)	Japan	China	Australia	RoW
Production shares[a]						
Labour, β^L	0.18	0.18	0.18	0.26	0.18	0.24
Skill, β^S	0.47	0.47	0.47	0.24	0.47	0.21
Capital, β^K	0.35	0.35	0.35	0.50	0.35	0.55
Income tax rates[b]						
$t^L = t^S = t^K$	0.02	0.02	0.13	0.04	0.10	0.07
Indirect tax rates[c]						
t^C	0.20	0.40	0.05	0.20	0.10	0.15
t^M	0.15	0.43	0.11	0.19	0.11	0.31
t^X	0.00	0.00	0.00	0.00	0.00	0.00
Money parameters[d]						
Reserve ratio, ρ	0.05	0.05	0.05	0.15	0.05	0.10
Cash ratio, μ	0.08	0.10	0.17	0.21	0.10	0.20
Elasticities						
c to r, ε^{CR}	0.10	0.10	0.10	0.10	0.10	0.10
c to Y^D, ε^{CY}	0.94	1.03	0.82	0.93	1.25	0.88
c_{ij}/c_{ik} to P^C_{ij}/P^C_{ik}, σ_i	2.00	2.00	2.00	2.00	2.00	2.00
Saving i^S_{ij} to r_i/r_j, σ^I_i	15.0	15.0	15.0	15.0	15.0	5.0
Investment, I_i to r^C_i/r_i, ε^I_i	1.00	1.00	1.00	1.00	1.00	1.00
Premium to G/T, ϕ_i	0.20	0.20	0.20	0.20	0.20	0.20
m^D to y, ε^{MY}	1.00	1.00	1.00	1.00	1.00	1.00
m^D to $(r+\pi^e)$, ε^{MR}	0.60	0.60	0.60	0.60	0.60	0.60

Note. a Production shares are based on demographic and occupational data from Tyers and Bain (2006), as well as estimates of factor incomes and capital stocks from the GTAP Database.

b These income tax rates are lower than observed because direct transfers and sovereign debt service are deducted from income tax revenue so that observed fiscal balances are consistent with T-G, where G includes only expenditure on goods and services.

c Although export taxes appear in the modelling, no values are applied since such taxes are usually very indirect. To infer the rates for other indirect taxes, approximate rates are initially chosen for the consumption tax rate and the import tax rate is then determined for consistency with the data on indirect tax revenue. In regions where other indirect taxes are major contributors to revenue, this tends to inflate the values of t^C and t^M.

d The money parameters are crude characterisations, made on the assumption that the EU behaves as if it had a single central bank to cover all 26 members. Money demand parameters stem from a survey of estimates used in other models (including McKibbin and Wilcoxen 1995, Knell and Stix, 2003 and Teles and Zhou 2005).

e Consumption elasticities are consistent with a variety of estimates in use in other models, both of marginal propensities and elasticities (including McKibbin and Wilcoxen 1995 and Jin 2011).

Appendix B

Experimental Closures and Shocks

Closures required to implement the experiments discussed in the text are detailed in Table A2, while the shocks are detailed in Table A3. The model code and working software are available on request from the author.

Table B1. Closures: choices of exogenous variables[a]

Liquidity traps in the US, the EU and Japan	Unconstrained conventional monetary policy
Labour market closure:	*Labour market closure:*
p_WN ! Nominal production wage, *W*	p_WN ! Nominal production wage, *W*
p_LD ! Employment of prodn workers, *L*	p_LD ! Employment of production workers, *L*
Fiscal policy closure:	*Fiscal policy closure:*
p_GN ! Nominal govt expenditure, *G*	p_GN ! Nominal government expenditure, *G*
p_SGN ! Government surplus, S_G	p_SGN ! Government surplus, S_G
Monetary policy targets:	*Monetary policy targets:*
Producer prices, P_P	Producer prices, P_P
p_PP("US")	p_PP("US")
p_PP("EU")	p_PP("EU")
p_PP("Japan")	p_PP("Japan")
p_PP("China")	p_PP("China")
p_PP("Australia")	p_PP("Australia")
p_PP("RoW")	p_PP("RoW")
Monetary base, M_B	Monetary base, M_B
p_MB("US")	p_MB("US")
p_MB("EU")	p_MB("EU")
p_MB("Japan")	p_MB("Japan")
p_MB("China")	p_MB("China")
p_MB("Australia")	p_MB("Australia")
p_MB("RoW")	p_MB("RoW")
Nominal exchange rate (non-US)[b], *E*	Nominal exchange rate (non-US)[b], *E*
p_EN("EU")	p_EN("EU")
p_EN("Japan")	p_EN("Japan")
p_EN("China")	p_EN("China")
p_EN("Australia")	p_EN("Australia")
p_EN("RoW")	p_EN("RoW")

Note. a These are commands required for solution by Gempack. Here the Rungem freeware format is used. Exclamation marks indicate lines are unread and retained here for clarity concerning the available exogenous variables, including the possible targets of monetary policy. The leading "p_" indicates percentage change.

b All exchange rates are defined relative to the US$, so there are just five.

Table B2. Pessimistic expectation shocks in the US, EU and Japana

Shocks (%) to Exogenous Expectational Variables
Consumer price inflation, which affects consumption, via $INFE = 1 + \pi^{Ce}$
Shock p_INFE("US") = -5;
Shock p_INFE("EU") = -5;
Shock p_INFE("Japan") = -5;
GDP price inflation, which affects money demand, via $RNFE = 1 + \pi^{Ye}$
Shock p_RNFE("US") = -5;
Shock p_RNFE("EU") = -5;
Shock p_RNFE("Japan") = -5;
Expected future nominal disposable income, $YDNE = Y^{De}$
Shock p_YDNE("US") = -10;
Shock p_YDNE("EU") = -10;
Shock p_YDNE("Japan") = -10;
Expected future net rate of return on installed capital, factor on $RCE \quad EXP = r_C^e$
Shock p_RC_EXP("US") = -2;
Shock p_RC_EXP("EU") = -2;
Shock p_RC_EXP("Japan") = -2;

Note. a These are commands required for solution by Gempack. Here again the Rungem freeware format is used. The leading "p_" indicates percentage change.