



Contents lists available at ScienceDirect

Journal of Macroeconomics

journal homepage: www.elsevier.com/locate/jmacro

Consumption home bias and exchange rate behavior

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ARTICLE INFO

Article history:

Received 16 November 2007

Accepted 2 August 2009

Available online xxxx

JEL classification:

E58

F32

F41

Keywords:

Consumption home bias

Exchange rate

Monetary shocks

ABSTRACT

This paper studies the response of the nominal exchange rate to monetary shocks in an economy with consumption home bias (CHB). When wages are sticky monetary shocks produce exchange rate dynamics. A liquidity effect and a net foreign asset effect determine the extent of these dynamics. I demonstrate that the exchange rate dynamics generated through these two channels are greater the more consumption is biased towards locally produced goods. I also show the influence of consumption home bias is stronger (weaker) when monetary shocks result in a negative (positive) net foreign asset position.

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1. Introduction

This paper studies the response of the nominal exchange rate to monetary shocks in a dynamic stochastic general equilibrium model of a small open economy with consumption home bias (CHB). Accounting for the exchange rate with CHB is important for two reasons. CHB is a feature of most major economies and fluctuations in the relative price of traded goods generate deviations from purchasing power parity without violating the law of one price. Monetary shocks produce exchange rate dynamics when there is CHB and wages are sticky. I demonstrate that more CHB leads to greater exchange rate dynamics, independent of the channels through which the dynamics are generated. Moreover, the influence of CHB is stronger (weaker) when monetary shocks result in a negative (positive) net foreign asset position.

The primary channel through which monetary shocks generate nominal exchange dynamics is a liquidity effect. When money demand is not unit elastic, shocks to money growth cause a reduction in the nominal interest rate. Given that uncovered interest parity (UIP) holds, the short run exchange rate overshoots its long run value. The response of the exchange rate also depends on the net foreign asset position. If the shock generates a negative (positive) net foreign asset position, exchange rate dynamics are greater (less). I take two approaches to demonstrate how CHB interacts with these two channels. I first provide analytical expressions by focusing on a situation in which agents can reset their wage each period. I then perform a quantitative analysis on the same basic framework, instead assuming that only a fraction of agents have the opportunity to reset their wage in any given period, and that money growth is autocorrelated. In both cases – analytical and simulated – the result is that more CHB leads to greater fluctuations in the exchange rate.

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Suppose that all agents have the possibility to reset their wage each period. At the beginning of time, after wages are set, there is a one period increase in the rate of money growth.¹ The shock causes the real interest rate to fall, the economy's terms of trade improve, and output rises. When the real and nominal sides of the economy interact, the monetary expansion induces a liquidity effect, and the uncovered interest parity condition implies the initial nominal exchange rate overshoots. All else equal, more CHB increases the magnitude of overshooting because the real side of the economy is more sensitive to the shock. The monetary expansion also causes long run net foreign asset accumulation if either the elasticity of substitution between domestic and foreign goods is relatively high, or, the intertemporal elasticity of substitution in consumption (overall) is relatively low. Changes in the net foreign asset position are reflected in the response of the long run exchange rate. Assume away the liquidity effect, and a positive net foreign asset position dampens the exchange rate's response to monetary shocks, versus the flex-wage case. More CHB magnifies the dampening effect because a larger accumulation of net foreign assets is required for a given trade deficit. When the liquidity effect and net foreign asset effect interact the same logic holds. Although, in general, both channels affect the long and short run exchange rate, the extent of overshooting is greater the more consumption is biased towards locally produced goods.

The same argument holds when agents face a constant probability of being able to reset their wage. When a shock hits, the real interest rate falls, the economy's terms of trade improve, and output rises above the steady state level for several quarters. All else equal, the associated liquidity effect is smaller when money growth is autocorrelated because agents also anticipate future changes in the rate of money growth. Overshooting is still present because output is persistent, and moreover, the greater CHB, the more persistence is output, and the greater the initial overshooting. Simulation results also show that the same is true for exchange rate volatility. Although higher levels of CHB are associated with more overshooting and greater volatility, asset accumulation also plays an important role. In particular, if the economy has a temporarily negative (positive) net foreign asset position, exchange rate overshooting and exchange rate volatility are greater (less). The net foreign asset position also affects the extent to which overshooting and volatility rise with CHB. If the economy runs a negative (positive) net foreign asset position, the influence of consumption home bias is stronger (weaker) for both.

This paper focuses on CHB as a source of deviations from purchasing power parity.² However, one might equally assume deviations from purchasing power parity arise from the breakdown of the law of one price for traded goods, due to pricing to market, or movements in the relative price of traded to non traded goods. Obstfeld and Rogoff's (2000) well-known objections to the pricing to market assumption are based on evidence that there is a negative correlation between the exchange rate and the terms of trade. They suggest that deviations from the law of one price arise because non traded goods prices are incorporated into the consumer price index for goods that appear tradable. However, at short and medium run horizons, the relative price of non traded goods contribute very little to fluctuations in the real exchange rate (Engel, 1999). Whilst fluctuations in the relative price of traded goods has received less attention, it is arguably as relevant for the majority of small open economies in generating movements in the real exchange rate. Quantitative analysis of the exchange rate when there is pricing to market can be found in Kollmann (2001), Chari et al. (2002), Monacelli (2004), Bergin (2003, 2006), and Jung (2007).³ The introduction of a non traded good has been analyzed by Lane (2001) and Hau (2002). Recently, Dotsey and Duarte (2008) have stressed the relevance of non traded goods over the pricing to market approach in matching exchange rate behavior along with other business cycle statistics.

This paper also focuses largely on the initial reaction of the exchange rate to monetary shocks. Evidence from VARs, such as those used by Eichenbaum and Evans (1995) and Kim and Roubini (2000), are not supportive of the idea that there is a short run over reaction of the exchange rate. They identify two puzzles. A perverse result in which the exchange rate depreciates when there is a monetary contraction; and a "delayed overshooting" result, where the peak response of the exchange rate is some months after the shock. Faust and Rogers (2003) also use a VAR analysis, but relax some of the zero contemporaneous restrictions typically used to identify open economy VARs. They find evidence of overshooting, and in the 'right' direction, but conclude this may be a result of non-monetary factors. Event studies, which rely on a weaker set of identifying assumptions, and restrict their attention to the impact reaction of the policy shock, are more supportive. Zettelmeyer (2004), for example, identifies monetary policy shocks by the reaction of three month market interest rate to policy announcements that were not themselves endogenous to economic news on the same day. Exchange rate depreciations are attributed to reverse causality, and a percentage contractionary shock appreciates the exchange rate by 2–3% on impact.

2. Model economy

The world economy is populated with a continuum of agents of unit mass. The population in the segment $[0, n]$ belong to the domestic economy and the population in the segment $(n, 1]$ belong to the foreign economy. Domestic households consume domestic and foreign goods, supply a differentiated labor type, hold real money balances, and non state contingent

¹ This is equivalent to a permanent and unanticipated change in the money stock, as in Dornbusch (1976).

² Warnock (2003) provides a characterization of the exchange rate when there is CHB using the two (symmetric) country framework of Obstfeld and Rogoff (1995). This paper generalizes Warnock's analysis along a number of dimensions. The intertemporal elasticity of substitution in consumption differs from one, the extent of (labor) market competition does not determine the strength of expenditure switching, and CHB depends on the degree of openness and the relative size of the economy.

³ This literature owes much to Betts and Devereux's (2000) original pricing to market extension of Obstfeld and Rogoff (1995). For the US, Gopinath and Rigobon (2007) find local currency pricing for imports and producer currency pricing for exports. See Gorodnichenko and Tesar (2009) for a related test of LOP.

domestic and foreign currency nominal bonds. Labor is immobile and households set the price at which they are willing to supply their labor at time t , with a constant probability, δ_w , that they will have the opportunity to reset at time $t + k$. Domestic firms produce a single specialized output using labor. Consumption, output and the nominal price of the domestic output are denoted with h -subscripts and for foreign consumption, output and prices f is used. Asterisks denote foreign economy variables.

2.1. Preferences, technology, and market clearing conditions

Household preferences and firm's technology take the following form in the domestic economy:

$$\begin{aligned} \mathbb{U}_0 &= \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{1}{1 - \sigma_c} C_t^{1 - \sigma_c} + \frac{\eta_m}{1 - \sigma_m} \left(\frac{M_t}{P_t} \right)^{1 - \sigma_m} - \frac{\eta_l}{1 + \sigma_l} l_t^{1 + \sigma_l} \right], \\ C_t &= \left[(1 - v)^{1/\lambda} C_{h,t}^{(\lambda-1)/\lambda} + v^{1/\lambda} C_{f,t}^{(\lambda-1)/\lambda} \right]^{\lambda/(\lambda-1)} \quad \text{and} \quad v \equiv \phi(1 - n), \\ y_t &= l_t^\alpha \quad \text{and} \quad l_t = \left[\frac{1}{n} \int_0^n l_t(z)^{(\theta-1)/\theta} dz \right]^{\theta/(\theta-1)}. \end{aligned}$$

In this setup, v is overall share of the foreign good in the domestic consumption basket, and is the measure of consumption home bias. It is comprised of two parameters; $\phi \in [0, 1]$, which measures the extent of trade openness, and n , which is the domestic population as a fraction of the world population, or country size. The parameter σ_c is the inverse of the intertemporal elasticity of substitution in consumption and λ is the elasticity of substitution in consumption between domestic and foreign outputs. The ratio σ_c/σ_m is the consumption elasticity of money demand and σ_m is the inverse interest elasticity of money demand. The Frisch elasticity of labor supply is $1/\sigma_l$ and returns to scale in production are given by $\alpha < 1$.

The remaining budget constraints and first-order conditions are relegated to [Appendix A](#). The domestic resource constraint is, $ny_t = \int_0^n C_{h,t}(z) dz + \int_n^1 C_{h,t}^*(z) dz$, where $C_{h,t}^*(z)$ represents total export sales, and y_t measures domestic per-capita output. I assume monetary policy is conducted using lump-sum taxes and transfers, where the rate of money growth is given by, $\mu_t \equiv M_t/M_{t-1}$, for $t = 0, \dots, \infty$. To close the model, I specify equilibrium in the money market, sum across the z agents, and set money demand equal to supply. In this case, ny_t is the aggregate level of output, and domestic goods markets clear when $P_{h,t}y_t = (1 - v)P_tC_t + [(1 - n)v^*/n]P_t^*C_t^*s_t$, with s_t denoting the nominal exchange rate.

The foreign economy is identical to the domestic economy except the overall share of the domestic good in it's consumption basket is $v^* \equiv n\phi^*$. Foreign residents can also only access foreign currency bonds. In the analysis below, I assume the domestic economy is approximately small, so the foreign economy, or, rest of the world, is approximately closed, and can be treated as exogenous from the perspective of the domestic economy.⁴

2.2. Linearized conditions for the domestic economy

To analyze the dynamic behavior of the model, I take a linear approximation of the equilibrium conditions around a zero inflation, zero trade balance steady state, with a zero initial level of net foreign assets. In the analysis below I rely on the following set of conditions:

$$\hat{y}_t = \left(\frac{\alpha}{\alpha - 1} \right) (\widehat{W}_t - \widehat{P}_{h,t}) \quad \text{and} \quad \hat{y}_t = \alpha \widehat{l}_t, \tag{1}$$

$$\mathbb{E}_t \widehat{C}_{t+1} = \widehat{C}_t + \frac{1}{\sigma_c} (\widehat{i}_t + \widehat{P}_t - \mathbb{E}_t \widehat{P}_{t+1}), \tag{2}$$

$$\mathbb{E}_t \widehat{s}_{t+1} = \widehat{s}_t + \widehat{i}_t - \widehat{i}_t^*, \tag{3}$$

$$\widehat{M}_t - \widehat{P}_t = \frac{1}{\sigma_m} \left[\sigma_c \widehat{C}_t - \left(\frac{\beta}{1 - \beta} \right) \widehat{i}_t \right], \tag{4}$$

$$\widehat{W}_{t,t} = \beta \delta_w \mathbb{E}_t \widehat{W}_{t,t+1} + (1 - \beta \delta_w) \left\{ \widehat{W}_t - (1 + \sigma_l \theta)^{-1} \left[(\widehat{W}_t - \widehat{P}_t) - (\sigma_c \widehat{C}_t + \frac{\sigma_l}{\alpha} \widehat{y}_t) \right] \right\}, \tag{5}$$

$$\widehat{W}_t = \delta_w \widehat{W}_{t-1} + (1 - \delta_w) \widehat{W}_{t,t}, \tag{6}$$

$$\widehat{P}_t = (1 - v) \widehat{P}_{h,t} + v \widehat{s}_t, \tag{7}$$

$$\hat{y}_t = (1 - v) \widehat{C}_t - \lambda \widehat{P}_{h,t} + (1 - v) \lambda \widehat{P}_t + v \lambda \widehat{s}_t + v \widehat{y}_t^*, \tag{8}$$

$$\beta \widehat{b}_t - \widehat{b}_{t-1} = \hat{y}_t + \widehat{P}_{h,t} - \widehat{P}_t - \widehat{C}_t. \tag{9}$$

All variables above represent deviations from their respective steady state values, except \widehat{b}_t , the net foreign asset position, which is scaled by output, since $b = 0$. Eq. (1) is the competitive output supply function, (2) is the consumption Euler equation, (3) is the uncovered interest parity (UIP) condition, and (4) is money demand. Eqs. (5) and (6) determine the evolution

⁴ A similar distinction between country size and trade openness is used, for example, in [Faia and Monacelli \(2008\)](#) and [DePaoli \(2009\)](#).

of the reset wage, $\widehat{W}_{t,t}$, and the wage index, \widehat{W}_t . The consumer price index (CPI) and resource constraint are given by (7) and (8). Finally, the national budget constraint is (9). Two exogenous variables affect the domestic economy; the foreign interest rate, \hat{i}_t^* , and foreign output, \hat{y}_t^* . From here on, I assume both are constant, and so $\hat{i}_t^* = \hat{y}_t^* = 0$.

3. Analytical results

In this section I make a number of simplifying assumptions to derive analytical results. I demonstrate how a liquidity effect and a net foreign asset effect interact with CHB to determine the impact of a money shock on the exchange rate. I assume the production technology is linear and the Frisch elasticity of labor supply is infinite ($\alpha = 1$ and $\sigma_l = 0$). I also assume individuals can reset the wage rate each period, and replace the Calvo-style wage setting equation, (5), with a static labor-leisure trade-off:

$$\widehat{W}_t - \widehat{P}_t = \sigma_c \widehat{C}_t.$$

Because agents reset their wage each period I also drop the equation governing the evolution of the wage index. Finally, I assume the monetary shock takes the form of an unanticipated and permanent change in the level of the money supply, such that, at date $t = 0$, \widehat{M}_t jumps from zero to \widehat{M} . This is equivalent to a one period change in the rate of money growth, such that, $\Delta \widehat{M}_0 \equiv \widehat{M}$ and $\Delta \widehat{M}_t = 0$ for $t \geq 1$.

3.1. Reduced form expressions for the exchange rate

Since agents are endowed with perfect foresight, markets clear in all periods after the shock, and in period $t = 1$ the economy reaches a new steady state. This implies $\hat{r}_t = 0$ for $t \geq 1$. Money demand and the consumption Euler equation determine aggregate demand. Applying the Fisher equation the nominal interest rate is, $\hat{i}_0 = \frac{(1-\beta)(\sigma_m-1)}{1+(1-\beta)(\sigma_m-1)} \hat{r}_0$ and $\hat{i}_t = 0$ for all $t \geq 1$.⁵ When $\sigma_m = 1$, $\hat{i}_0 = 0$, so given the shock I consider, the nominal interest rate jumps immediately to its new steady state, ruling out the possibility of a liquidity effect. Only when $\sigma_m \neq 1$ does the real side of the economy affect the nominal side, potentially generating a fall in the nominal interest rate from a monetary expansion. In the open economy, equilibrium in financial markets requires the UIP condition to hold; $\hat{i}_0 = \hat{s} - \hat{s}_0$, where \hat{s} is the long run exchange rate (that is, for periods $t \geq 1$). Using the CPI, and the definition of the real exchange rate, I derive a reduced form expression for the short run nominal exchange rate:

$$\hat{s}_0 = \left[1 + \frac{\varrho(1-\sigma_m)\phi}{1-(1-\sigma_m)(1-\nu)} \right] \hat{s} + \left[\frac{\varrho\sigma_m}{1-(1-\sigma_m)(1-\nu)} \right] \widehat{M}, \quad (10)$$

$$\varrho \equiv \frac{(1-\nu)(1-\beta)(\sigma_m-1)}{1+\nu(1-\beta)(\sigma_m-1)}.$$

This reduced form shows that if monetary shocks are to generate exchange rate dynamics the interest elasticity of money demand cannot be one. When $\sigma_m = 1$, because there is no liquidity effect, the long and short run nominal exchange rates coincide, and this rules out the type of overshooting in Dornbusch (1976). Moreover, when $\sigma_m > 1$, ϱ is positive, and a decreasing function of ν . This implies, for a given long run exchange rate, more CHB leads to a larger initial jump in the exchange rate.

To provide a closed-form solution for the initial exchange rate, I solve the national budget constraint forward. Ruling out Ponzi schemes, and assuming the initial level of government debt is zero, $\sum_{t=0}^{\infty} \beta^t (\hat{y}_t + \widehat{P}_{h,t} - \widehat{P}_t - \widehat{C}_t) = 0$. Because the economy reaches a new steady state in the period after the shock, I split this intertemporal constraint into two periods. In the initial period, I impose $\widehat{P}_{h,0} = 0$, as production is linear and wages are preset, and in all periods after the shock I impose labor market clearing, $\widehat{P}_h - \widehat{P} = \sigma_c \widehat{C}$. Applying the UIP and consumption Euler equations, I derive a reduced form for the long run nominal exchange rate:

$$\hat{s} = (1-\Phi)(1-\beta)\hat{i}_0 + \Phi \left(1 - \frac{1}{\sigma_c} \right) (1-\beta)\hat{r}_0 + \Phi \widehat{\Omega} + (1-\Phi)\beta \widehat{P}_h, \quad (11)$$

$$\Phi \equiv \frac{1}{\lambda + (1-\phi)(\lambda-1)} \quad \text{and} \quad \widehat{\Omega} \equiv \widehat{C} + \widehat{P}.$$

This reduced form makes clear that there is an interaction between the liquidity effect present in (10) and the response of the current real interest rate and the future period GDP deflator. Because this reduced form is derived from the national intertemporal budget constraint, the reaction of the real interest rate and GDP deflator also determine whether the country moves away from a zero net foreign asset position as a result of the shock. Before analyzing the reaction of the economy in detail, consider the simplest case, which eliminates exchange rate and net foreign asset dynamics. When $\sigma_m = 1$, then $\hat{s}_0 = \hat{s}$, in (10). From (11), when $\lambda = 1$, then $\Phi = 1$, and \widehat{P}_h drops out; and when $\sigma_c = 1$, \hat{r}_0 drops out. In this case, we also find

⁵ This condition also pins down the monetary dynamics of the economy. Consider the general expression that makes \hat{i}_t a function of the endogenous variables, \hat{i}_{t-1} and \hat{r}_t . Since the nominal interest rate is non-predetermined, the expression needs to be unstable in its forward dynamics, and satisfy a saddle path property, where \hat{r}_t can be treated as an exogenous forcing variable. Since $\hat{r}_t = 0$ for $t \geq 1$, when money growth is constant at $\mu_t = \mu$, it must be that $\hat{i}_t = 0$ for $t \geq 1$.

$\widehat{\Omega}_0 = \widehat{\Omega}$, and the solution for the exchange rate is $\widehat{s} = \widehat{M}$. Thus, despite wage setting, the reaction of the exchange rate to the shock is as it would be if wages were flexible. This is because the increase in output, consumption, and the terms of trade (which is a multiple of $\widehat{P}_{h,t} - \widehat{P}_t$) that result from the shock ‘net out’. There is no change in the trade balance, and as the initial net foreign asset position is zero, the net foreign asset position remains at zero, and the real effect of the shock lasts only until wages are revised.

3.2. Analysis of the exchange rate

I now analyze how CHB interacts both with the liquidity effect and the net foreign asset position. In all cases, a positive monetary shock improves the terms of trade and lowers the real interest rate. Since the terms of trade and real interest rate impact consumption choices, the effect of the shock on borrowing or lending internationally depends on the inter and intra-temporal elasticities of substitution in consumption. Any change in the net foreign asset position is also reflected in the long run response of the nominal exchange rate to the shock. Specifically, allowing λ to vary, and fixing $\sigma_c = 1$ reflects the impact of domestic agents switching expenditure from foreign to domestic goods, whilst allowing σ_c to vary, and fixing $\lambda = 1$, determines the extent of shifting (overall) expenditure intertemporally. If we rule out a liquidity effect, we need only consider (11) to analyze this case. Both possibilities are relatively straightforward because the relationship between the GDP deflator and the real interest rate is unaffected, versus the benchmark case. Specifically, $\widehat{r}_0 = -(1 - \nu)\widehat{P}_h$ and $\widehat{P}_h = \widehat{M}$. Allowing for both generalizations, I derive the following expressions for the exchange rate, in each case:

$$\widehat{s} = \left[\frac{1 + \beta(\lambda - 1)(2 - \nu)}{1 + (\lambda - 1)(2 - \nu)} \right] \widehat{M} \quad \text{or} \quad \widehat{s} = \left[\frac{1 + \beta(\sigma_c - 1)(1 - \nu)}{1 + (\sigma_c - 1)(1 - \nu)} \right] \widehat{M}. \quad (12)$$

I find that the exchange rate is proportionally less than the benchmark case if $\lambda > 1$, in the first case, and if $\sigma_c > 1$, in the second. In both cases, the greater CHB; that is, the closer ν is to one, the greater the dampening effect on the exchange rate. Note that the magnitude of the change in the exchange rate differs in each case, and this is also related to the presence of the CHB term. When $\lambda > 1$, the impact of expenditure switching is a relatively strong, leading to a initial trade surplus, matched by a long run accumulation of net foreign assets and a trade deficit. This is possible because the accumulation of net foreign assets generates wealth for domestic agents. Wealthier agents are less willing to supply labor, but still able to enjoy a higher level of consumption. When $\sigma_c = \lambda = 1$, $\widehat{C}_{h,0} = \widehat{M}$ and $\widehat{C}_{f,0} = 0$. However, when $\lambda > 1$, $\widehat{C}_{h,0} > \widehat{M}$ and $\widehat{C}_{f,0} < 0$; that is, there is a relatively large boost to consumption of the domestic good. Finally, when $\sigma_c > 1$, although the shock also causes an initial trade surplus, we find $0 < \widehat{C}_{h,0} < \widehat{M}$ and $\widehat{C}_{f,0} > 0$.

As the monetary expansion generates a fall in the real interest rate, when $\sigma_m \neq 1$, there are also exchange rate dynamics. If we assume $\sigma_c = \lambda = 1$, long run monetary neutrality holds, and the long run reaction of the exchange rate to the shock is consistent with the benchmark case. Using (10), the short run exchange rate is given by the following:

$$\widehat{s}_0 = \left[\frac{1 + (1 - \beta)(\sigma_m - 1)}{1 + \nu(1 - \beta)(\sigma_m - 1)} \right] \widehat{M}. \quad (13)$$

Because the long run change in the exchange rate is proportional to the shock, gauging the extent of the initial reaction of the exchange rate only requires us to compare that over reaction to the magnitude of the shock itself. Exchange rate overshooting occurs if money demand is relatively interest elastic. The extent of overshooting is greater when consumption is more home biased. The logic of this result is the following. The exchange rate response to the shock derives from the liquidity effect; $\widehat{i}_0 = \frac{(1 - \beta)(\sigma_m - 1)}{1 + (1 - \beta)(\sigma_m - 1)} \widehat{r}_0$. There is no CHB parameter in this expression. But, $\widehat{r}_0 = -(1 - \nu)(1 + \varrho)\widehat{M} < 0$ is increasing in magnitude as CHB rises, because the real side of the economy is more exposed to the shock.

In general, when the two channels interact, it is still possible to derive explicit expression for the exchange rate in the long and short run. The solution can be expressed in the following way:

$$\widehat{s}_0 = \left[1 + \frac{\varrho(1 - \sigma_m)\nu}{1 - (1 - \sigma_m)(1 - \nu)} \right] \widehat{s}(\sigma_c, \lambda, \widehat{M}) + \left[\frac{\varrho\sigma_m}{1 - (1 - \sigma_m)(1 - \nu)} \right] \widehat{M},$$

where the term $\widehat{s}(\sigma_c, \lambda, \widehat{M})$ captures the impact of the net foreign asset position on both the long and short run exchange rate. The extent of overshooting is now a potentially complicated function of all the underlying parameters of the model. However, with more CHB the initial reaction of the exchange rate increases. If agents accumulate net foreign assets, the magnitude of the change in both the short and long run exchange rate is less, but the magnitude of overshooting rises with CHB.

4. Quantitative results

I now present quantitative results for a dynamic version of the model to determine the impact of CHB on exchange rate overshooting and exchange rate volatility. In doing so, the staggered wage setting mechanism is re-introduced, via (5) and (6). I also assume the rate of money growth is autocorrelated with parameter $0 \leq \rho < 1$:

$$\Delta \widehat{M}_t = \rho \Delta \widehat{M}_{t-1} + \varepsilon_t, \quad (14)$$

Table 1
Calibration

Calibration of parameters.		
Parameter	Description	Base value
σ_C	Coefficient of relative risk aversion in consumption	1.25
σ_m	Coefficient of relative risk aversion in real balances	10
σ_l	Intertemporal elasticity of labor supply	0.47
λ	Degree of substitutability of traded goods	1.75
ν	Degree of consumption home bias	0.25
β	Subjective discount factor	0.96
α	Curvature in production function	0.8
δ_w	Calvo probability that wages are adjusted	0.75
θ	Elasticity of substitution between labor types	6
κ_b	Capital mobility parameter	0.003
ρ	Autoregressive parameter for money growth	0.15

where ε_t is a normally distributed random variable. Setting $\rho = 0$ with $\varepsilon_t = 0$ for all $t \geq 1$ replicates the shock analyzed above. To allow the calculation of second moments, I follow Benigno (2009) and include a risk premium that captures the cost of domestic households holding net foreign assets. I suppose households are charged a premium on the foreign interest rate as borrowers and receive a payoff lower than the foreign interest rate as lenders. This assumption implies that the UIP condition needs to be amended. In linear terms, this gives:

$$\hat{i}_t = \mathbb{E}_t \hat{s}_{t+1} - \hat{s}_t - \kappa_b \hat{b}_t, \quad (15)$$

where $\kappa_b > 0$.⁶ To simulate the model, I use the method outlined in Binder and Pesaran (1996), which in this case transforms the system of equations – (1)–(9), with (15) replacing (3), and (14) – into the following:

$$\mathbf{A}Z_t = \mathbf{B}Z_{t-1} + \mathbf{C}\mathbb{E}_t Z_{t+1} + \mathbf{D}X_t,$$

where the vector Z_t contains the variables $[\hat{y}_t \ \widehat{W}_t \ \widehat{W}_{t,t} \ \hat{s}_t \ \hat{P}_t \ \hat{P}_{h,t} \ \hat{m}_t \ \hat{Q}_t \ \hat{b}_t \ \Delta \hat{M}_t]'$ ($\hat{m}_t \equiv \hat{M}_t - \hat{P}_t$ denotes real money balances) and the vector X_t contains the money growth shock.⁷ The baseline values used for calibration are shown in Table 1.

For the baseline calibration of money demand, I choose $\sigma_C = 1.25$, $\sigma_m = 10$ and $\beta = 0.96$. This implies that the semi-elasticity of money demand with respect to the interest rate is $\frac{1}{\sigma_m} \left(\frac{\beta}{1-\beta} \right) = 2.4$, which is the conservative end of what Ball (2001) suggests. The consumption elasticity of money demand is $\frac{\sigma_C}{\sigma_m} = 0.125$. The intertemporal elasticity of labor substitution is set to $\sigma_l = 0.47$, as in Rotemberg and Woodford (1997), and $\delta_w = 0.75$. The elasticity of substitution between imports and domestic goods is set at $\lambda = 1.75$. I assume there is a 30 basis point spread on domestic holdings of net foreign assets, which implies $\kappa_b = 0.003$. The autoregressive parameter on the money growth process is set at $\rho = 0.15$, as in Kollmann (2001). Finally, the CHB parameter is set at $\nu = 0.25$, which is a 25% import share of GDP.

Given the parameters in the baseline specification, we would already expect the model to deliver exchange rate and net foreign asset dynamics ($\sigma_C > 1$ and $\lambda > 1$ both imply an accumulation of net foreign assets, with a zero net foreign asset position in the long run, due to $\kappa_b > 0$) We would also expect the liquidity effect to deliver exchange rate overshooting ($\sigma_m > 1$), but mitigated by the autocorrelation of the money growth rate ($\rho > 0$). Additional persistence in the rate of money growth is known to dampen the liquidity effect in DSGE models. When autocorrelation is high, the shock can raise expectations of future money growth sufficiently to cause an increase in the nominal interest rate. Fig. 1 shows the effect of a one percent shock to money growth in the initial period, for the baseline specification.

The impulse response functions confirm the analytic results in Section 3. A positive innovation to money growth raises output and consumption (not shown). Agents accumulate net foreign assets. Overtime, all of these series return to their steady state values. The stimulus for these changes are the reduction in the real and nominal interest rates, consistent with the initial rise and fall of the nominal exchange rate. In this particular case, on impact, the exchange rate rises by around 1.5% from the steady state level, whereas the long run change is around 1.2%. Thus the exchange rate overshoots its long run value. However, what needs to be determined is how the magnitude of overshooting changes with CHB. Using the impulse response functions, I calculate the extent of overshooting using the difference between the initial and long run exchange rate; $\hat{s}_0 - \hat{s}$, for a range of the CHB parameter, $\nu \in (0.05, 0.95)$. The calculation for six cases are plotted in Fig. 2.

To interpret the figure consider the thick solid line ('Analytic'). This line corresponds to Eq. (13), when $\beta = 0.96$ and $\sigma_m = 10$. It shows $\hat{s}_0 - \hat{s}$, for the different values of ν , which is the inverse of CHB.⁸ The line is always above zero on the vertical axis, which implies $\hat{s}_0 > \hat{s}$ for all values of CHB. Overshooting is greater the more CHB. In the five non analytic cases, I determine

⁶ As is well known, asset accumulation imparts a unit root to all the underlying variables, which would undermine the stochastic analysis. See Schmitt-Grohe and Uribe (2003), and also Bergin (2006), in the context of monetary models.

⁷ The details are in Appendix B.

⁸ In this case, the calculation is trivial because the economy reaches its long run equilibrium in period $t = 1$, and the long run value of the exchange rate is one, when $\Delta \hat{M} = 1$.

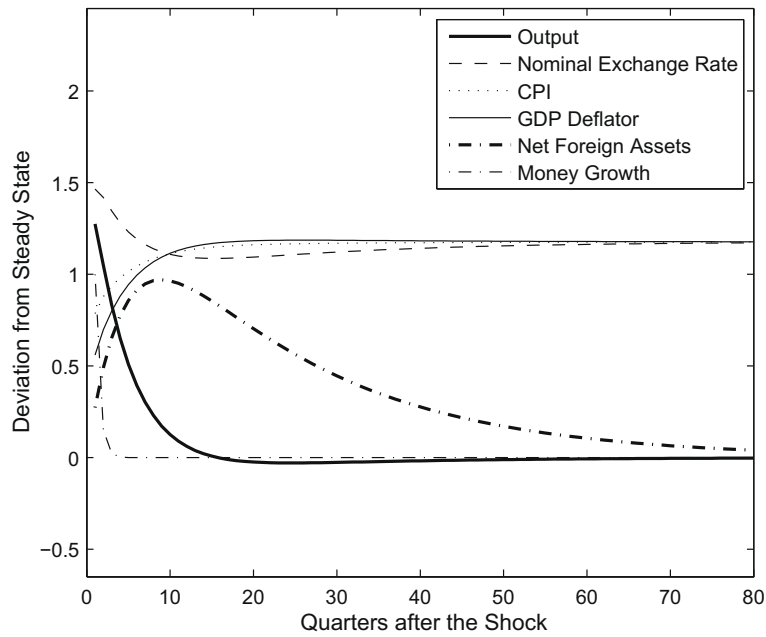


Fig. 1. Impulse response functions.

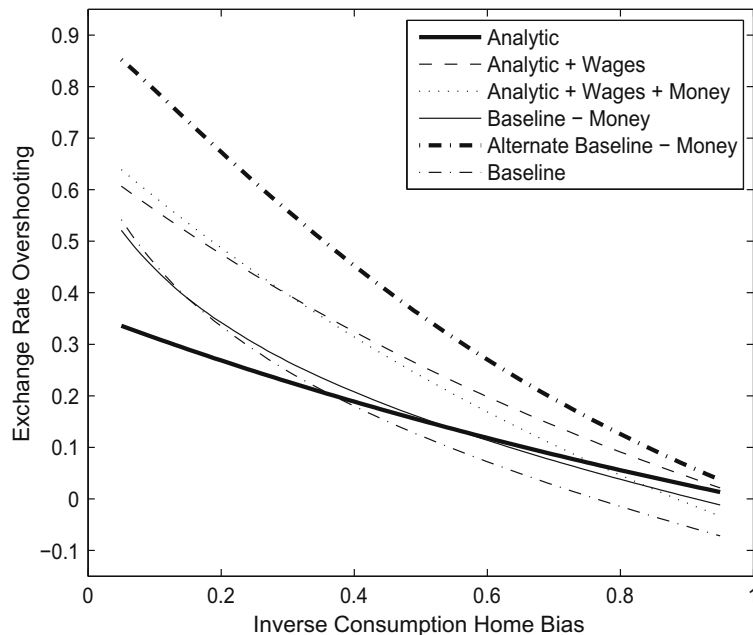


Fig. 2. Exchange rate overshooting.

the value of δ as that when the economy has converged to the new steady state. Since the net foreign asset position is stationary, this only depends on the autocorrelation of money growth. In these cases, as CHB rises, exchange rate overshooting is greater.

There are other important results. The dashed line ('Analytic + Wages') uses the same parameter restrictions as (13), but incorporates the staggered wage setting structure to isolate the effects of adding persistence. In this case, I assume $\delta_w = 0.75$ and $\theta = 6$. It is immediate that adding persistence through wage contracts increases overshooting, at all levels of CHB. This is consistent with the textbook model of overshooting in the sense that as the goods market – here labor market – is slower to adjust, the asset market compensates. The dotted line ('Analytic + Wages + Money') uses the same set of parameters, but I

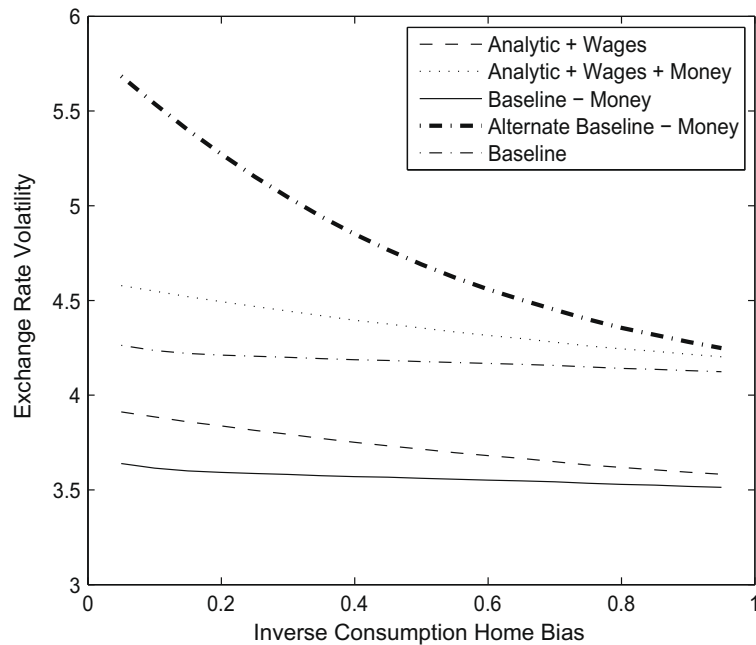


Fig. 3. Exchange rate volatility.

also assume the rate of money growth is autocorrelated, with parameter $\rho = 0.15$. The shock now raises expectations of future money growth which can eliminate the liquidity effect. Compared to the case when money growth is not autocorrelated, the extent of overshooting is greater if the economy is relatively home biased, but at $\nu = 0.3$, the lines cross and overshooting is less.

I also consider the implications of asset accumulation which, in general, dampens the response of the exchange rate to monetary shocks. To understand how the net foreign asset channel works, I consider three cases. The dash-dot line ('Baseline') is consistent with the impulse responses in Fig. 1. The thick dash-dot line ('Alternate Baseline-Money') instead assumes $\sigma_c = 0.8$, $\lambda = 0.75$, and $\rho = 0$. The remaining parameters are consistent with the baseline case to isolate the effect of a temporary negative net foreign asset position. The solid line ('Baseline-Money') assumes $\rho = 0$. Again, the remaining parameters are consistent with the baseline case, now to isolate the interaction of the liquidity effect and asset accumulation. In the baseline case, a temporary accumulation of net foreign assets creates a dampening effect on overshooting. Overshooting is also less sensitive to changes in CHB and, in extreme cases, when the economy is relatively less consumption home biased, despite $\sigma_m = 10$, there may be undershooting. Reducing the autocorrelation of money growth versus the baseline case ('Baseline-Money') makes this less likely. For the alternative setting of $\sigma_c = 0.8$ and $\lambda = 0.75$, which generates a temporary negative net foreign asset position, overshooting is greater. Finally, the line ('Analytic + Wages') is always bounded by ('Baseline-Money') from below and ('Alternate Baseline-Money') from above, confirming the analytic results of Section 3.

I now consider exchange rate volatility for the different parameterizations used to determine overshooting.⁹

The volatilities presented in Fig. 3 are consistent with those found in studies that focus on other mechanisms, such as the presence of non traded goods, or pricing to market, to generate exchange rate volatility. Here, I find that if consumption is more home biased, then exchange rate volatility is greater. There is a caveat to this simple result, however, because the CHB-exchange rate volatility relationship is more sensitive to the response of the net foreign asset position than the CHB-overshooting relationship. When the parameters of the model are set consistent with a temporary positive net foreign asset position ('Baseline'), exchange rate volatility is reduced, which is consistent with the overshooting results. However, exchange rate volatility is less response to changes in CHB than exchange rate overshooting. When the parameters of the model are set consistent with a temporary positive net foreign asset position and money growth is not autocorrelated ('Alternate Baseline-Money'), exchange rate volatility is strictly greater than the former case, for any level of CHB. Consumption home bias also has a relatively strong impact on the volatility. Again, the two cases associated with movements in the net foreign asset position also bound the cases where there is no change in the net foreign asset position, both in terms of volatility and the sensitivity of exchange rate volatility to CHB. One interpretation of these results is that there are important implications of incomplete international financial markets for exchange rate volatility and monetary shocks, but this depends on the pattern of external adjustment. Whilst this is also true for exchange rate overshooting, it is less so.

⁹ The theoretical statistics – % standard deviations – are averages of moments computed over 10,000 simulation runs with a length of 88 periods each.

5. Conclusion

Monetary shocks produce exchange rate fluctuations when there is CHB and wages are sticky. In all the cases I consider, the more domestic households are biased in the consumption of goods produced locally, the greater are the dynamics in the exchange rate. That is despite the law of one price holding. The key part of this story is a liquidity effect. When there are shocks to money growth, the nominal interest rate falls, and the short run exchange rate overshoots. The extent of overshooting also depends on the net foreign asset position. If the economy has a temporary positive (negative) net foreign asset position, the extent of overshooting is smaller (greater) and CHB exerts a relatively smaller (greater) effect on exchange rate overshooting and volatility.

Acknowledgements

I have received helpful comments from Philip Lane, Neil Rankin, seminar participants in Copenhagen, Leuven, Warwick, and an anonymous referee. Financial support from the ESRC (#R42200134107) is gratefully acknowledged. I also thank IDS, at the University of Sussex, for their hospitality during December 2008.

Appendix A. Derivation of non-linear equations

This appendix derives the conditions for a two country model (focusing on the domestic economy) with consumption home bias. Labor is the only input to production and there are decreasing returns to scale; $y_t = l_t^\lambda$, and $l_t = \left[\frac{1}{n} \int_0^n l_t(z)^{(\theta-1)/\theta} dz \right]^{\theta/(\theta-1)}$. Firms cost minimize, which results in a labor demand condition, $l_t(z) = (W_t(z)/W_{t,t})^{-\theta} l_t$, and once we assume households have a constant probability δ_w of changing price, a wage index:

$$W_t = \left[\delta_w W_{t-1}^{1-\theta} + (1 - \delta_w) W_{t,t}^{1-\theta} \right]^{1/(1-\theta)}. \quad (16)$$

We find the following competitive output supply function from profit maximization:

$$y_t = (W_t/\alpha P_{h,t})^{\alpha/(\alpha-1)}. \quad (17)$$

Households consume domestic and foreign goods. They maximize consumption, subject to an expenditure constraint; that is $C_t = \left[(1 - \nu)^{1/\lambda} C_{h,t}^{(\lambda-1)/\lambda} + \nu^{1/\lambda} C_{f,t}^{(\lambda-1)/\lambda} \right]^{\lambda/(\lambda-1)}$ with $P_t C_t = P_{h,t} C_{h,t} + P_{f,t} C_{f,t}$. This gives the following micro demand equations for each good; $C_{h,t} = (1 - \nu) \left(\frac{P_t}{P_{h,t}} \right)^\lambda C_t$ and $C_{f,t} = \nu \left(\frac{P_t}{P_{f,t}} \right)^\lambda C_t$, where:

$$P_t = \left[(1 - \nu) P_{h,t}^{1-\lambda} + \nu P_{f,t}^{1-\lambda} \right]^{1/(1-\lambda)} \quad (18)$$

is the CPI. The (upper) utility function and budget constraint for the domestic individual are,

$$\mathbb{U}_0 = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{1}{1 - \sigma_c} C_t^{1-\sigma_c} + \frac{\phi_m}{1 - \sigma_m} \left(\frac{M_t}{P_t} \right)^{1-\sigma_m} - \frac{\phi_l}{1 + \sigma_l} l_t^{1+\sigma_l} \right]$$

and,

$$s_t \left[B_t - \frac{B_{t-1}}{(1 + i_t^*) \cdot \kappa_b \left(\frac{s_t B_t}{P_t} \right)} \right] + \frac{A_t}{(1 + i_t)} - A_{t-1} = \vartheta_t + W_t(z) l_t(z) - P_t C_t + M_{t-1} - M_t - T_t.$$

As in Benigno (2009), the cost function, here denoted κ_b , drives a wedge between the return on foreign currency denominated bonds received by domestic and by foreign residents, rationalized by assuming the existence of foreign-owned intermediaries in the foreign asset market who apply a spread over the risk-free rate of interest when borrowing or lending to domestic agents in foreign currency. This spread depends on the net foreign asset position of the domestic economy. Foreign households receive profits from the intermediaries in the form of lump-sum transfers. Domestic households maximize utility, subject to their budget constraint, and the demand for their labor type. Using λ_t as the lagrange multiplier on the budget constraint, and substituting the second constraint into both the objective function and the first constraint, we the following first-order conditions:

$$\lambda_t = 1/P_t C_t^{\sigma_c}, \quad (19)$$

$$1 = (1 + i_t) \beta \mathbb{E}_t \frac{\lambda_{t+1}}{\lambda_t}, \quad (20)$$

$$s_t \lambda_t = \mathbb{E}_t s_{t+1} \lambda_{t+1} (1 + i_t^*) \cdot \kappa \left(\frac{s_t B_t}{P_t} \right), \quad (21)$$

$$\phi_m \left(\frac{M_t}{P_t} \right)^{-\sigma_m} \frac{1}{P_t} = \lambda_t - \beta \mathbb{E}_t \lambda_{t+1}. \quad (22)$$

Finally, there is a Calvo wage setting equation:

$$0 = \mathbb{E}_t \left\{ \sum_{k=0}^{\infty} (\beta\theta_w)^k \left[\frac{W_{t,t}(z)}{P_{t+k}} C_{t+k}^{-\sigma_c} - \Phi_{t+k}(z)^{\sigma_l} \right] l_{t+k}(z) \right\}, \quad (23)$$

where $\Phi \equiv \phi_l[\theta/(\theta - 1)]$.

Aggregating the resource constraint $(ny_t = \int_0^n C_{h,t}(z)dz + \int_n^1 C_{h,t}^*(z)dz)$ and applying the micro demands, gives the goods market clearing condition:

$$y_t = (1 - v) \left(\frac{P_t}{P_{h,t}} \right)^\lambda C_t + \frac{1 - n}{n/\nu^*} \left(\frac{P_t^*}{P_{h,t}^*} \right)^\lambda C_t^*. \quad (24)$$

The national budget constraint is derived by aggregating over the individuals' budget constraints, applying the government budget constraint, $T_t = M_{t-1} - M_t$, and recognizing, that in equilibrium, $A_t = 0$. This gives:

$$s_t \left[B_t - \frac{B_{t-1}}{(1 + i_t^*) \cdot \kappa_b \left(\frac{s_t B_t}{P_t} \right)} \right] = P_{h,t} y_t - P_t C_t. \quad (25)$$

I apply a linear approximation to (16)–(25), around a point of zero inflation and balanced trade. These conditions are used to determine (1)–(9).

Appendix B. Linear system

I simulate the model using the method described in Binder and Pesaran (1996). Along with the conditions outlined in the text, I include the following definition to account for shocks to money growth; $\hat{m}_t + \hat{P}_t - \Delta \hat{M}_t = \hat{m}_{t-1} + \hat{P}_{t-1}$, where $\hat{m}_t \equiv \hat{M}_t - \hat{P}_t$. The solution can be written in the following way:

$$\begin{aligned} \mathbf{A} \mathbf{Z}_t &= \mathbf{B} \mathbf{Z}_{t-1} + \mathbf{C} \mathbb{E}_t \mathbf{Z}_{t+1} + \mathbf{D} \mathbf{W}_t, \\ \mathbf{Z}_t &= \left[\hat{y}_t \quad \widehat{W}_t \quad \widehat{W}_{t,t} \quad \hat{s}_t \quad \hat{P}_t \quad \hat{P}_{h,t} \quad \hat{m}_t \quad \widehat{\Omega}_t \quad \hat{b}_t \quad \Delta \widehat{M}_t \right]', \end{aligned}$$

where,

$$\mathbf{A} = \begin{bmatrix} 0 & 1 & \delta_w - 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ -\gamma \left(\frac{\sigma_l}{\alpha} \right) & -\gamma \sigma_l \theta & 1 & 0 & \gamma(\sigma_c - 1) & 0 & 0 & -\gamma \sigma_c & 0 & 0 \\ 0 & 0 & 0 & -\left(\frac{\beta}{1-\beta} \right) & \sigma_c & 0 & \sigma_m & -\sigma_c & -\left(\frac{\beta}{1-\beta} \right) \kappa_b & 0 \\ \frac{\alpha-1}{\alpha} & -1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & -v\lambda & (v-1)(\lambda-1) & \lambda & 0 & v-1 & 0 & 0 \\ 0 & 0 & 0 & -v & 1 & v-1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 & -1 \\ 0 & 0 & 0 & -1 & 1 - \sigma_c & 0 & 0 & \sigma_c & -\kappa_b & 0 \\ 1 & 0 & 0 & 0 & 0 & 1 & 0 & -1 & \beta & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

with $\gamma \equiv (1 - \beta\delta_w)/(1 + \sigma_l\theta)$ and $\kappa_b \equiv -\kappa'(b)y$. The lag and lead matrices are,

$$\mathbf{B} = \begin{bmatrix} 0 & \delta_w & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & \rho \end{bmatrix} \quad \text{and} \quad \mathbf{C} = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & \beta\delta_w & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & -\left(\frac{\beta}{1-\beta} \right) & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & -1 & 1 - \sigma_c & 0 & 0 & \sigma_c & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}.$$

Finally, $\widehat{\mathbf{D}} = [0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 0 \ 1]'$ contains the shock.

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