



Credit frictions and co-movement of durable and non-durable goods in a small open economy

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Abstract

In this paper I investigate, numerically, the co-movement puzzle by testing the ability of borrowing and lending constraints to counter the opposite movement of durable and non-durable goods in response to foreign monetary policy and international bond shocks. I do this by simulating a small open economy sticky price model calibrated to the South African economy over the period 1990Q012014Q04. I show that introducing borrowing and lending constraints into a small open economy sticky price model, in the face of foreign monetary policy tightening and an international bond shock, partially solves the co-movement puzzle. This is because the shadow value of durable goods reduces the incentive to accumulate durables for collateral because foreign lenders are less efficient than domestic lenders at recovering loans. In the case of sticky durables and sticky non-durables, the sticky price model mimics a fall in the relative price of durable goods observed in the data. Thus, financial frictions such as borrowing and lending constraints make it possible to reconcile the sticky price model with the data.

JEL codes: E44, E52, F41, F42

Keywords: Credit frictions, borrowing constraint, lending constraint, durable goods, non-durable goods, sticky prices, co-movement puzzle, small open economy

1 Introduction

Multi-sector sticky price models produce unusual outcomes when the prices of durable goods are flexible. This is because, on the one hand, as empirical evidence suggests, a monetary policy shock results in the positive movement of aggregate consumption in both durable and non-durable goods sectors. On the other, it is because the movement of durable goods is greater than that of non-durable goods, as suggested by Erceg and Levin (2002, 2006). On the other hand, Barsky et al. (2003) show that in a two-sector economy with flexibly priced durable goods and sticky priced

non-durable goods, the flexibility of prices of durable goods governs the response of aggregate consumption to a monetary policy tightening. This is because the shadow value of durable goods is approximately constant owing to the typically high stock-to-flow ratio of durable goods. Thus, the responsiveness of the user cost of durable goods does not result in an improvement in total utility for the households.¹

The phenomenon in which the consumption of durable goods and the consumption of non-durable goods co-move in the same direction in the data but in the opposite direction in sticky price models is known as the co-movement puzzle (Barsky et al., 2003; Monacelli, 2009). The puzzle is due to the negative correlation between the user cost and the relative price of durable goods (durables). This is because consumption of non-durable goods (non-durables) is conditional on consumption smoothing, as predicted by the permanent income hypothesis (Barsky et al., 2003). In the face of a monetary policy shock, households can substitute intertemporally in reaction to changes in the relative price of non-durables, but the shadow value of durables is nearly constant, allowing little intertemporal elasticity of substitution for durables. Thus, a small, intertemporal increase in the relative price of durables results in a large shift of consumption away from the durables sector.

To solve the co-movement puzzle, Barsky et al. (2003) propose the introduction of frictions in the form of credit constraints, sticky wages and sticky inputs into sticky price models. Incorporating a binding borrowing constraint into a sticky price model generates a disconnect between the marginal utility of extra durable purchases and the relative price of durables. This is because, assuming that incomes rise in the wake of a monetary policy shock, constrained borrowers may spend their extra income purchasing durables although non-durables have become relatively cheaper. The extra income also relaxes the borrowing constraint, thus making the demand for durables dependent on income (GDP) rather than on the aggregate stock of durables. Monacelli (2009) formalizes this idea in a two-sector sticky price model in which borrowing households face a borrowing constraint. He shows that whenever prices of durable goods are flexible and prices of non-durable goods are sticky, a monetary policy tightening results in a decrease in the relative price of durables. The user cost of consumption rises in the durable goods and falls in the non-durables sector. The co-movement puzzle is thus solved by connecting the shadow value of durables to the shadow value of borrowing. Sterk (2010) and Chen and Liao (2014) revisit the Monacelli (2009) framework and show that flexible durable prices are required to solve the co-movement puzzle.

This paper investigates, numerically, the co-movement puzzle by examining the ability of bor-

¹In the literature, the terms "stock", "purchases" and "consumption" are also used to refer to goods (durable and non-durable). For clarity, in this paper I have used "goods" throughout.

rowing and lending constraints to explain the opposite movement of durable and non-durable goods in response to a foreign monetary policy shock and an international bond shock. The aim is to discover whether a small open economy sticky price (SOE-SP) model that is augmented with credit frictions can solve the co-movement puzzle. I augment the SOE-SP model with a borrowing constraint, following Iacoviello and Manetti (2006) and lending constraint, following Manetti and Peng (2013). Similar models that use credit frictions to explain the co-movement puzzle have been tested in recent milestone papers by Monacelli (2009), Sterk (2010) and Chen and Liao (2014).

The contribution of the paper is that it investigates the co-movement puzzle for small open economies, thus expanding the new-Keynesian DSGE literature on credit frictions and the fundamental characteristics of durable goods and non-durable goods. Methodologically, the paper enhances Monacelli (2009) and Sterk (2010) by introducing the dynamics of small open economies. To the best of my knowledge, this is the first paper to tackle the co-movement puzzle for small open economies.

The results show that in response to foreign monetary policy tightening and an international bond shock, the introduction of credit frictions into a SOE-SP model partially solves the co-movement puzzle. In the case of sticky durables and sticky non-durables, the SOE-SP model mimics a fall in the relative price of durable goods observed in the data. Thus, credit frictions such as borrowing and lending constraints make it possible to reconcile the SOE-SP model with the data.

The rest of paper is organized as follows. The next section presents the SOE-SP model, Section 3 reports the numerical results, and Section 4 concludes.

2 A SOE-SP model with credit frictions

The main framework of this paper is a two-sector SOE-SP model. In each sector, there are households consisting of savers and borrowers, perfectly competitive final goods producers and monopolistically competitive intermediate goods producers. Households supply labor hours of work to producers from which they earn wage payment. The model incorporates credit frictions in the form of a lending constraint, and domestic and foreign borrowing constraints subject to an exogenous international bond shock. Durables are used as collateral against borrowing. Monetary policy is implemented using a foreign nominal interest rate via the country specific risk premium.

2.1 Borrowers

Representative borrowers of measure ς maximize the expected lifetime utility function:

$$E_o \sum_{t=0}^{\infty} \beta^t \left[\log X_t - \frac{\nu N_t^{1+\varphi}}{1+\varphi} \right], \quad (1)$$

where β^t is the borrowers' discount factor, N_t is the labor hours, ν is the preference parameter for hours worked, φ is the inverse elasticity of labor supply and X_t is the total aggregate consumption specified as:

$$X_t = \left[(1-\omega)^{\frac{1}{\varkappa}} C_t^{\frac{\varkappa-1}{\varkappa}} + \omega^{\frac{1}{\varkappa}} D_t^{\frac{\varkappa-1}{\varkappa}} \right]^{\frac{\varkappa}{\varkappa-1}}, \quad (2)$$

where ω is the share of durable goods, \varkappa is the elasticity of substitution between durables and non-durables irrespective of country of production, C_t is consumption of non-durable goods and D_t is the stock of durable goods.

Consumption of non-durable goods is specified by a Dixit-Stiglitz aggregator:

$$C_t \equiv \left[(1-\alpha)^{\frac{1}{\eta}} C_{h,t}^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}} C_{f,t}^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}, \quad (3)$$

where $\alpha \in [0, 1]$ is inversely connected to the degree of home bias. That is, the portion of domestic non-durable goods assigned to imported goods is taken as an index of openness, following Galí and Monacelli (2005). $\eta > 1$ is a measure of substitutability between domestic and foreign goods.

$C_{h,t}$ and $C_{f,t}$ are respectively given by the constant elasticity of substitution (CES) functions:

$$C_{h,t} = \left(\int_0^1 C_t(J)^{\frac{\varepsilon_J}{\varepsilon_J-1}} dJ \right)^{\frac{\varepsilon_J}{\varepsilon_J-1}} \quad \text{and} \quad C_{f,t} = \left(\int_0^1 C_{f,t}(J)^{\frac{\gamma-1}{\gamma}} dJ \right)^{\frac{\gamma}{\gamma-1}},$$

where $J \in [0, 1]$ denotes a continuum of differentiated final non-durables produced by each country, $\varepsilon_J > 1$ is the elasticity of substitution between varieties of goods produced in any given country and γ is the substitutability of goods produced in different foreign countries.

The optimal allocations of expenditure between domestic and imported non-durables after derivation of their respective demand functions, as in Galí and Monacelli (2005), are:

$$C_{h,t} = (1-\alpha) \left(\frac{P_t^h}{P_t} \right)^{-\eta} C_t \quad \text{and} \quad C_{f,t} = \alpha \left(\frac{P_t^h}{P_t} \right)^{-\eta} C_t,$$

where $P_t \equiv \left[(1-\alpha) P_{h,t}^{1-\eta} + \alpha P_{f,t}^{1-\eta} \right]^{\frac{1}{1-\eta}}$ is the consumer price index (CPI).

Borrowers maximize Eq. 1 subject to a budget constraint specified as:

$$P_{c,t}C_t + P_{d,t}(D_t - (1 - \delta)D_{t-1}) + R_{t-1}^h B_{t-1}^h + \Xi(F A_{t-1}) e_t R_{t-1}^f B_{t-1}^f = B_t^h + e_t B_t^f + W_t N_t + T_t. \quad (4)$$

where B_t is end-of-period t nominal debt, R_{t-1} is the nominal lending rate on loan contracts required at time $t - 1$, e_t is the real exchange rate, W_t is the nominal wage, N_t is the total labor supply and T_t is government transfers. The upper and lower case letters denote nominal and real variables respectively.

Labor is assumed to be perfectly mobile across sectors, implying that the nominal wage rate is common across sectors (Monacelli, 2009). B_t^f is an exogenous international bond and follows an AR(1) process, $B_t^f = \rho_B B_{t-1}^f - \epsilon_{B_t^f}$ with $\epsilon_{B_t^f} \sim i.i.d. (0, \sigma_{B^f}^2)$. $\Xi(F A_t)$ is the country-specific risk premium function, following Gelain and Kulikov (2009) and Schmitt-Grohe and Uribe (2003), specified as:

$$\Xi(F A_{t-1}) \equiv (-\phi_{fa} F A_t).$$

where $F A_t \equiv \frac{e_t B_t^f}{P_t^h}$ is the net foreign asset position and ϕ_{fa} is the country-specific risk premium parameter.

In real terms, budget constraint Eq. 4 is expressed as:

$$C_t + q_t (D_t - (1 - \delta)D_{t-1}) + R_{t-1}^h B_{t-1}^h + \Xi(F A_{t-1}) R_{t-1}^f \frac{e_t}{e_{t-1}} B_{t-1}^f = B_t^h + B_t^f + w_t N_t + \tau_t. \quad (5)$$

where the relative price of durables is $q_t \equiv \frac{P_{d,t}}{P_{c,t}}$, and gross inflation is in units of non-durable goods $\pi_{c,t} \equiv \frac{P_{c,t}}{P_{c,t-1}}$.

In addition to the period budget constraint Eq. 4, borrowers face an endogenous domestic constraint and foreign borrowing constraints, following Iacoviello and Minetti (2006) and Minetti and Peng (2013), specified in real terms as:

$$R_t^h B_t^h \leq E_t(\sigma \chi_h q_{t+1} D_t), \quad (6)$$

$$R_t^f B_t^f \leq E_t((1 - \sigma) \chi_f q_{t+1} D_t), \quad (7)$$

where σ is the share of durable goods D_t used by borrowers as collateral and χ is the loan-to-value ratio. Borrowers would prefer to exhaust their credit in the domestic market. However,

because savers face a lending constraint, that is $\chi_h > \chi_f$, full domestic borrowing is not achievable. Borrowers therefore supplement domestic borrowing with foreign borrowing.

Letting the shadow value of domestic borrowing constraints be λ_t^h and the shadow value of foreign borrowing constraints be λ_t^f , borrowers' first-order conditions in units of non-durables are:

$$w_t = \frac{\nu}{\left[(1-\alpha)^{\frac{1}{\eta}} + \alpha^{\frac{1}{\eta}}\right] \left[(1-\omega)^{\frac{1}{1-\varepsilon}}\right]} \frac{N_t^\varphi}{C_t}, \quad (8)$$

$$\frac{1}{C_t} = \beta^t E_t \left(\frac{1}{C_{t+1}} \frac{R_t^h}{\pi_{c,t+1}} \right) + \lambda_t^h R_t^h, \quad (9)$$

$$\frac{1}{C_t} = \beta^t E_t \left(\frac{1}{C_{t+1}} \Xi(F A_t) \frac{e_{t+1}}{e_t} \frac{R_t^f}{\pi_{c,t+1}} \right) + \lambda_t^f R_t^f, \quad (10)$$

$$\frac{1}{C_t} q_t = \beta^t E_t \frac{1}{C_{t+1}} \left(\frac{1}{D_t} + q_{t+1} \right) + E_t \left[\lambda_t^h \sigma \chi_h q_{t+1} + \lambda_t^f (1-\sigma) \chi_f q_{t+1} \right]. \quad (11)$$

Eq. 8 is the real wage equation. Eq. 9 is the Euler equation for holding domestic bonds. Eq. 10 is the Euler equation for holding foreign bonds. Eq. 11 is the borrowers' demand for durable goods where $\lambda_t^h \sigma \chi_h q_{t+1} + \lambda_t^f (1-\sigma) \chi_f q_{t+1}$ is the shadow value of durables. The shadow value of durables implies that the optimal selection of the share of durables σ equates to the marginal benefit of domestic and foreign collateral as $\lambda_t^h \chi_h = \lambda_t^f \chi_f$. Therefore, by purchasing more durables, borrowers shift consumption from non-durables. This in turn increases their current credit limit and future consumption of non-durables. Eq. 11 can be expressed in terms of the user cost of durables $Z_t = \frac{D_t}{C_t}$ as:

$$Z_t \equiv \frac{1}{q_t} \left\{ E_t \frac{\beta^t}{C_{t+1}} D_t q_{t+1} + D_t E_t \left[\lambda_t^h \sigma \chi_h q_{t+1} + \lambda_t^f (1-\sigma) \chi_f q_{t+1} \right] \right\}. \quad (12)$$

2.2 Savers

Savers of measure $(1-\varsigma)$ invest in domestic government bonds earning a gross nominal interest rate in period t and own monopolistic producers in each sector. They maximize the utility function:

$$E_o \sum_{t=0}^{\infty} \zeta^t \left[\log \tilde{X}_t - \frac{\nu \tilde{N}_t^{1+\varphi}}{1+\varphi} \right], \quad (13)$$

with $\zeta \succ \beta$ implying that savers are more patient than borrowers and therefore discount the future less heavily.

Subject to the budget constraint:

$$P_{c,t}\tilde{C}_t + P_{d,t}\left(\tilde{D}_t - (1 - \delta)\tilde{D}_{t-1}\right) + \tilde{B}_t^h = R_{t-1}^h\tilde{B}_{t-1}^h + W_t\tilde{N}_t + \tilde{T}_t, \quad (14)$$

where \tilde{C}_t , \tilde{D}_t , \tilde{B}_t , \tilde{N}_t , and \tilde{T}_t are respectively savers' consumption of non-durables, savers' consumption of durables, end-of-period t nominal debt, labor supply and government transfers. It is assumed that there are no aggregate nominal profits from the holdings of monopolistic competitive producers in sector j . In real terms, the budget constraint Eq. 14 is expressed as:

$$\tilde{C}_t + q_t\left(\tilde{D}_t - (1 - \delta)\tilde{D}_{t-1}\right) + \tilde{B}_t^h = R_{t-1}^h\tilde{B}_{t-1}^h + w_t\tilde{N}_t + \tau_t, \quad (15)$$

Savers also face a lending constraint, following Minetti and Peng (2013), specified as:

$$\tilde{B}_t^h \leq \hat{\sigma}\left(R_{t-1}^h\tilde{B}_{t-1}^h + q_t\tilde{D}_{t-1}\right), \quad (16)$$

where $\hat{\sigma}$ is a constant used as savers' proxy for capital-adequacy ratio.

Letting λ'_t be the shadow value of the savers' lending constraint, savers' first-order conditions in units of non-durables are:

$$w_t = \frac{\nu}{\left[(1 - \alpha)^{\frac{1}{\eta}} + \alpha^{\frac{1}{\eta}}\right] (\omega)^{\frac{1}{1-\alpha}}} \frac{\tilde{N}_t^\varphi}{\tilde{C}_t}, \quad (17)$$

$$\frac{1}{\tilde{C}_t} + \lambda'_t = \zeta^t E_t \left(\frac{1}{\tilde{C}_{t+1}} \frac{R_t^h}{\pi_{c,t+1}} \right) + \lambda'_{t+1} \hat{\sigma} R_t^h, \quad (18)$$

$$\frac{1}{\tilde{C}_t} q_t = \frac{j}{\tilde{D}_t} + \zeta^t E_t \left(\frac{1}{\tilde{C}_{t+1}} q_{t+1} + \lambda'_{t+1} \hat{\sigma} q_{t+1} \right). \quad (19)$$

Eq. 17 is savers' real wage equation. Eq. 18 is savers' Euler equation for holding domestic bonds. Eq. 19 is savers' intertemporal consumption of non-durables.

2.3 Final goods producers

Perfectly competitive final goods producers purchase units of intermediate good i and operate the production function:

$$Y_{j,t} = \left(\int_0^1 Y_{j,t}(j)^{\frac{\varepsilon_j - 1}{\varepsilon_j}} dj \right)^{\frac{\varepsilon_j}{\varepsilon_j - 1}},$$

where $j = c, d$ and ε_j is the elasticity of substitution between different varieties in sector j .

The final goods producers maximize profits. The demand functions for the typical intermediate

good i in sector j , expressed as:

$$Y_{j,t}(i) = \left(\frac{P_{j,t}^h(i)}{P_{j,t}^h} \right)^{-\varepsilon_j} Y_{j,t}.$$

for all i . Therefore, $P_{j,t}^h \equiv \left[\int_0^1 P_{j,t}^h(i)^{1-\varepsilon_j} di \right]^{\frac{1}{1-\varepsilon_j}}$ is the price index consistent with the final goods producer in sector j earning zero profits.

2.4 Intermediate goods producers

Monopolistic competitive intermediate goods producer i in sector j hires labor supplied by borrowers and faces a linear production technology function given by:

$$Y_{j,t}(i) = N_{j,t}(i). \quad (20)$$

where $N_{j,t}(i)$ is total demand for labor by producer i in sector j . Labor productivity is assumed to be constant and normalized to 1 in both sectors. Each producer i has monopolistic power to set its prices and face a Rotemberg (1982) type quadratic price adjustment cost proportional to output: $\frac{v_j}{2} \left(\frac{P_{j,t}^h(i)}{P_{j,t-1}^h(i)} - 1 \right)^2 Y_{j,t}$. Where $v_j \succeq 0$ is the degree of sectoral nominal price rigidity and determines the size of the price adjustment cost. Prices are flexible in the case $v_j = 0$.

The intermediate goods producer i maximizes the expected discounted nominal profit:

$$E_0 \left[\sum_{t=0}^{\infty} \Lambda_{j,t} \left\{ P_{j,t}^h(i) Y_{j,t}(i) - w_t N_{j,t}(i) - \frac{v_j}{2} \left(\frac{P_{j,t}^h(i)}{P_{j,t-1}^h(i)} - 1 \right)^2 P_{j,t}^h Y_{j,t} \right\} \right]. \quad (21)$$

subject to Eq. 12. In Eq. 21, $\Lambda_{j,t} \equiv \zeta E_t \left(\frac{\tilde{\lambda}_{t+1}}{\lambda_t} \right)$ is savers' stochastic discount factor in which $\tilde{\lambda}_t$ is savers' marginal utility of nominal income. Letting $\frac{P_{j,t}^h(i)}{P_{j,t}^h}$ be the relative price of variety i in sector j , in a symmetric equilibrium in which $\frac{P_{j,t}^h(i)}{P_{j,t}^h} = 1$ for all i and j , and all producers employ the same amount of labor in each sector, the first order condition for intermediate goods producer i 's maximization problem is:

$$((1 - \varepsilon_j) + \varepsilon_j mc_{j,t}) = v_j (\pi_{j,t}^h - 1) \pi_{j,t}^h - v_j E_t \left\{ \frac{\Lambda_{j,t+1}}{\Lambda_{j,t}} \frac{P_{j,t+1}^h}{P_{j,t}^h} \frac{Y_{j,t+1}}{Y_{j,t}} (\pi_{j,t+1}^h - 1) \pi_{j,t+1}^h \right\}. \quad (22)$$

where $\pi_{j,t}^h \equiv \frac{P_{j,t}^h}{P_{j,t-1}^h}$ is the gross inflation rate in sector j , and the real marginal cost in sector j is $mc_{j,t} = \frac{W_t}{P_{j,t}^h}$.

Log-linearizing around a sectoral zero-inflation steady state, Eq. 22 takes the form of a forward-looking new-Keynesian Phillips curve:

$$\widehat{\pi}_{j,t}^h = \zeta^t E_t \left(\widehat{\pi}_{j,t+1}^h \right) + \frac{\varepsilon_j - 1}{v_j} \widehat{mc}_{j,t}. \quad (23)$$

where a hat denotes the percentage deviation from the respective steady state value.

2.5 Small open economy dynamics

In the SOE-SP model, bilateral terms of trade between the domestic and the foreign country are defined by letting terms of trade $S_{i,t} = \frac{P_{i,t}^f}{P_t^h}$. This is the price of non-durables produced in foreign country i in terms of the domestic country. Therefore, the effective terms of trade are given by:

$$S_t \equiv \frac{P_{f,t}}{P_{h,t}} = \left(\int_0^1 S_{i,t}^{1-\gamma} di \right)^{\frac{1}{1-\gamma}}. \quad (24)$$

Dividing through households demand functions yields the relation, $\frac{C_{f,t}}{C_{h,t}} = \frac{\alpha}{(1-\alpha)} S_t^\eta$.

Gross inflation in units of non-durables $\pi_{c,t}$ is linked to the CPI inflation through the CPI index (Gali and Monacelli, 2005). Thus, in steady state, the CPI index satisfies a purchasing power parity condition given by:

$$\pi_t = \pi_t^h \frac{\left(\alpha + (1-\alpha) S_t^{1-\eta} \right)^{\frac{1}{1-\eta}}}{\left(\alpha + (1-\alpha) S_{t-1}^{1-\eta} \right)^{\frac{1}{1-\eta}}}. \quad (25)$$

In addition, exchange rate dynamics are derived from Eq. 24 as follows. The index of openness and the terms of trade are the gap between the two measures of change in price as a fraction of percentage change in terms of trade. Assuming that the law of one price applies for households' non-durables and defining $P_{i,t}(j) = g_{i,t} P_{i,t}^i(j)$ for all countries, where $g_{i,t}$ is the bilateral nominal exchange rate and $P_{i,t}^i(j)$ is the price of differentiated goods in country i expressed in the producer's currency, substituting for $P_{i,t}(j)$ and log linearizing around a steady state yields:

$$p_{f,t} = \int_0^1 (\xi_{i,t} + p_{i,t}^i) di = \xi_t + p_t^f, \quad (26)$$

where $\xi_t \equiv \int_0^1 \xi_{i,t} di$ is the (log) nominal effective exchange rate and $P_{i,t}^i \equiv \int_0^1 P_{i,t}^i(j) dj$ represents the (log) domestic price index for country i . Defining the bilateral real exchange with country i to be $e'_{i,t} \equiv \frac{g_{i,t} P_t^i}{P_t}$, and letting $e_t \equiv \int_0^1 e_{i,t} di$ be the (log) effective real exchange rate, where $e_{i,t} \equiv \log e'_{i,t}$, the real exchange rate is given by (Gali and Monacelli, 2005; Faia and Iliopoulos, 2011):

$$e_t = \left[\alpha (S_t)^{\eta-1} + (1 - \alpha) \right]^{\frac{-1}{1-\eta}} = e(S_t), \quad (27)$$

Durable goods are assumed to be non-tradable, therefore the real exchange rate e_t does not cause changes in the relative price of durable goods.

Following Gelain and Kulikov (2009), Eqs. 9 and 10 result in a modified uncovered interest rate parity (UIP) that takes into account a country specific risk specified as:

$$R_t^h = \Xi (FA) R_t^f. \quad (28)$$

2.6 Foreign monetary policy and market clearing conditions

The UIP condition in Eq. 28 implies that the domestic nominal interest rate is connected to the foreign nominal interest rate through the country specific risk premium function. Therefore, the monetary policy is conducted by means of an AR (1) process foreign interest rate rule:

$$R_t^f = \rho_R R_{t-1}^f + \epsilon_{R_t^f}. \quad (29)$$

where $\epsilon_{R_t^f} \sim i.i.d. (0, \sigma_R^2)$.

The necessary market clearing conditions are as follows. For markets to clear in the domestic economy, domestic households' expenditure on durables must equal aggregated domestic production and costs associated with prevailing resources originating from price adjustments. The aggregate consumption of the durables sector and the non-durables sector is the same in domestic and foreign economies. Therefore:

$$Y_{c,t} = \varsigma C_t + (1 - \varsigma) \tilde{C}_t + \frac{v_c}{2} (\pi_{c,t} - 1)^2 Y_{c,t}, \quad (30)$$

$$Y_{d,t} = \varsigma (D_t - (1 - \delta) D_{t-1}) + (1 - \varsigma) \left[\left(\tilde{D}_t - (1 - \delta) \tilde{D}_{t-1} \right) \right] + \frac{v_d}{2} (\pi_{d,t} - 1)^2 Y_{d,t}. \quad (31)$$

The debt market clears as follows:

$$\varsigma B_t^h + (1 - \varsigma) \tilde{B}_t^h = 0 \text{ and } B_t^f = 0. \quad (32)$$

The labor market clears as follows:

$$Y_t = \varsigma N_t + (1 - \varsigma) \tilde{N}_t. \quad (33)$$

Finally, the fiscal authority does not issue transfers to mitigate economic fluctuations. Hence:

$$\tau_t = 0. \quad (34)$$

2.7 Deterministic steady state conditions

The deterministic steady state conditions are as follows. Inflation is zero in both the durable and non-durable goods sectors. The shadow value of debt is always positive. This implies that households prefer to hold positive amounts of credit. Evaluating Eq. 9 using the standard steady state Lucas asset price equation $R = \beta^{-1}$ yields:

$$\lambda^t = (\zeta^t - \beta^t) \succ 0. \quad (35)$$

Further, evaluating Eq. 10 in steady state combined with Eq. 35, domestic borrowers' consumption of durables is presented as:

$$\frac{D}{C} = \frac{\alpha}{1-\alpha} q \{ [1 - (1-\delta)(\beta + \chi(\beta - \zeta))] \}^{-\eta}. \quad (36)$$

whereas $\delta \rightarrow 0$ (non-durability of goods) coupled by $\beta = \zeta$, (non-binding collateral constraints, $\lambda = 0$), implies that q is the only determinant of the margin on consumption of durable or non-durable goods.

Notice that collateral as a requirement for borrowing is isomorphic to the debt elastic interest rate. That is, an increase in the credit limit results in a decrease in demand for durable goods as collateral. Intuitively, as it becomes more difficult for domestic borrowers to convert collateral into new foreign debt, the attractiveness of durable goods as collateral diminishes.

3 Numerical analysis

The model is solved using simulation techniques calibrated to the South African economy by computing the averages of quarterly time series data for the period 1990Q01-2014Q04.² Parameters are also set following the literature.

3.1 Calibrated parameters

Table 1 presents the calibrated parameter coefficients. The durables' depreciation rate δ , is obtained from quarterly values of $\frac{D}{Y}$, Following Patroba and Raputsoane (2016). This results in an annual

²The data are also obtained from the South African Reserve Bank's Quarterly Bulletin.

depreciation rate of 0.19. The share of durables $\omega = 0.18$ is calculated from quarterly values of $\frac{D}{C+D}$. The value is consistent with Hoosain (2012), who obtained a ratio of 0.2 for South Africa. In steady state, the gross real interest rate equals the inverse of the subjective discount factor $1 + R = \frac{1}{\beta}$. The average annual deposit rate, proxied by the discount rate on 91-day treasury bills, is calculated to be 11 percent and the average annual lending rate, proxied by the prime overdraft rate, is calculated to be 15 percent. This implies that the discount factor for savers $\zeta = 0.90$ and the discount factor for borrowers $\beta = 0.87$.

The degree of openness is obtained from the sum of exports and imports as a share of GDP per capita resulting in $\alpha = 0.54$, compared to 0.48 estimated by du Plessis et al. (2014). The value is 0.3 in the empirical literature for developed countries. The degree of nominal rigidity in the non-durables sector v_c is set to create a frequency of four quarters on price adjustment. That is, following the standard Calvo-Yun model by letting θ be the probability of not re-setting prices, $\frac{1}{1-\theta} = 4$. This implies that $\theta = 0.75$ and an average frequency of price adjustment of one year. In each sector, therefore, the stickiness parameter satisfies $v_j = \theta(\varepsilon_j - 1) / (1 - \theta)(1 - \zeta\theta)$. The simulation tests alternative degrees of price stickiness with full flexibility achieved by setting $v_j = 0$.

The elasticity of labor supply $\varphi = 1$. The elasticity of substitution between domestic and foreign goods $\eta = 0.591$ as in Steinbach et al. (2009). The elasticity of substitution between varieties of goods $\varepsilon = 6$ as in Alpanda et al. (2010), implying a steady state mark-up $\mu = 0.2$. The elasticity of substitution between durables and non-durables $\kappa = 0.2$. The preference parameter $\nu = 0.3$, implying that, on average, South African households prefer to work a third of their time endowment. The share of durable goods used as domestic collateral $\sigma = 0.5$. The domestic loan-to-value ratio $\chi_h = 0.80$ and the foreign loan-to-value ratio $\chi_f = 0.40$ following Minetti and Peng (2013). Finally, the persistence of the foreign monetary policy shock $\rho_{R,f} = 0.9$ with a standard deviation of 0.01.

Table 1: Calibrated parameters

Parameter	δ	ω	ζ	β	α	θ	ϕ	η	ϵ	χ	ν	σ	χ_h	χ_f
Value	0.19	0.18	0.90	0.87	0.54	0.75	1	0.591	6	0.2	0.3	0.5	0.8	0.4

3.2 The effects of a foreign monetary policy tightening

Figure 1 plots the impulse response functions (IRFs) of non-durables, durables, relative price of durables, user cost of durables and domestic debt in response to a foreign monetary policy shock. The IRFs predict a varied restriction of price stickiness, namely sticky non-durables' and flexible durables' prices, sticky durables' and flexible non-durables' prices and equally sticky durables' and non-durables' prices. In the IRFs, the unbroken (green) line shows the reaction of the SOE-SP

model when non-durables have sticky prices and durables have flexible prices. The figure shows that the co-movement problem occurs up to the third period, through which the relative price of durables is constant. After the third period, the relative price of durables now falls and is accompanied by a rise in consumption of both non-durables and durables. The relative price of durables falls after the third period because the prices in the non-durables sector rise more than those in the durables sector.

The broken (blue) line shows the reaction of the SOE-SP model when durables have sticky prices and non-durables have flexible prices. The figure shows that the co-movement problem occurs again up to the fifth period, during which the relative price of durables falls. This is because there is a disconnect between the relative price and user cost of durables in response to the monetary policy shock (Monacelli, 2009). That is, the drop in the relative price of durables causes a tightening of borrowing requirements, resulting in a decrease in the demand for durables. This is particularly evident in Figure 1 in the initial increase in the demand for durables followed by a steep decline in demand up to the third period and an equally steep decline in domestic debt up to the fourth period. The marginal increase in the user cost of durables causes a substitution effect from durables to non-durables up to the fourth period, followed by larger increases in the durables sector than in the non-durables sector. From the fifth period, the relative price of durables is constant and is accompanied by constant movement of consumption of non-durables and a marginal rise in consumption of durables.

The spiky (red) line shows the reaction of equally sticky non-durables and durables to foreign monetary policy tightening. The figure shows that the co-movement problem occurs up to the fifth period, during which the relative price of durables falls. Subsequently, the relative price of durables becomes constant and is accompanied by a marginal decline in consumption of non-durables and near constancy in consumption of durables. It can therefore be concluded from Figure 1 that the co-movement problem occurs up to the third period, after which the problem is resolved in the face of a monetary policy tightening.

According to Barsky et al. (2007), Monacelli (2009), Sterk (2010) and Chen and Liao (2014), solving the co-movement puzzle requires that a model predicts a decrease in both non-durables and durables. This is because of a typically high stock-to-flow ratio of durables that is due to the marginal benefit of durables being dependent on the stock of durables and the almost infinite elasticity of substitution between durables and non-durables. This implies that additional purchase of durables by households, due to the responsiveness to the durables' own user cost, does not improve the households' total utility.

The drop in the relative price of durables, in the case of sticky durables, is as a result of the

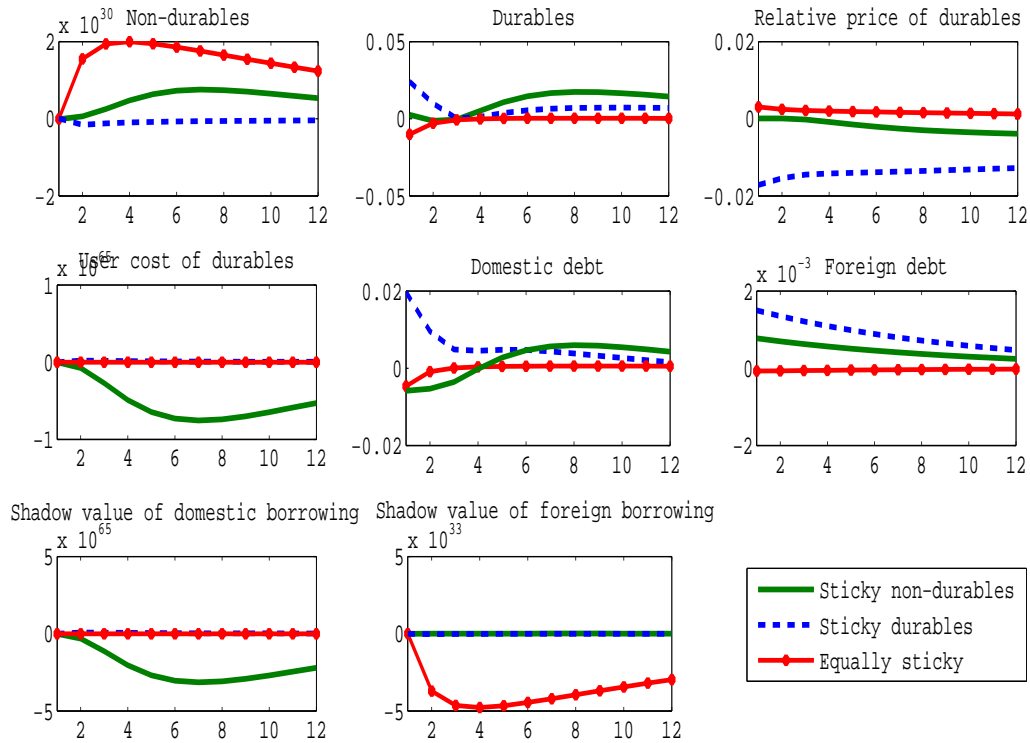


Figure 1: Impulse responses to a foreign monetary policy tightening: effect of varying the degree of stickiness

interaction between the borrowing constraint and the lending constraint, as shown by Minetti and Peng (2013). On the one hand, the decrease in the relative price of durables caused by the foreign monetary policy tightening results in a reduction in the net worth of the domestic lenders, thereby tightening the borrowing constraint. This in turn compels domestic borrowers to borrow from foreign lenders to meet their loan demand. On the other hand, given that borrowers have borrowed partly from the domestic market, their borrowing from the foreign market, up to their debt limit, is dependent on the value of durables not committed for domestic borrowing. This implies that the amount of credit borrowed from the domestic market is greater than that borrowed from the foreign market. Therefore, the drop in the relative price of durables causes tightening of the lending constraint and helps to achieve equilibrium in the durables market.

In Figure 2, I test the effects of the shadow value of durables to consumption of durables and consumption of non-durables for both savers and borrowers. To do this, I establish the impact of the shadow value of durables given its important characteristics in determining the direction of movement between durables and non-durables. The figure shows a negative co-movement of consumption of durables and consumption of non-durables in response to a foreign monetary policy shock, and a positive co-movement between the two variables in response to an international bond

shock.

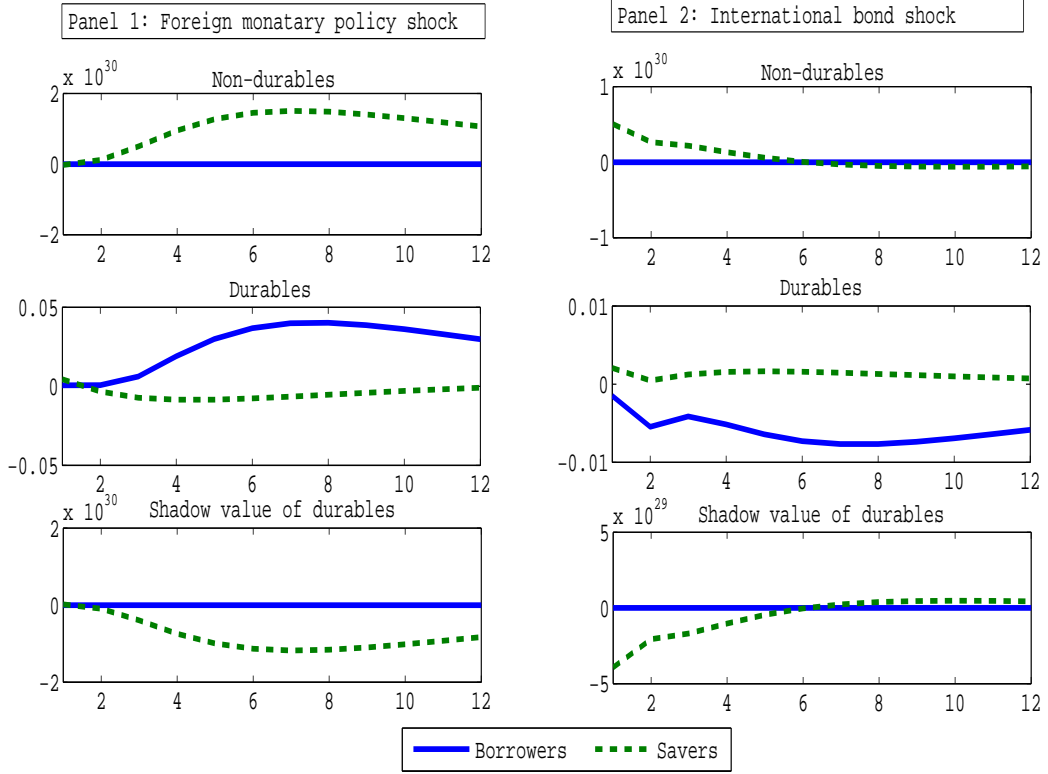


Figure 2: Impulse responses to a foreign monetary policy tightening and an international bond shock: effects of shadow value of durable goods

It can be concluded from Figures 1 and 2 that, in response to a foreign monetary policy tightening, the introduction of credit frictions into a SOE-SPM partially solves the co-movement puzzle. This can be attributed to the shadow value of durables $[\lambda_t^h \sigma \chi_h q_{t+1} + \lambda_t^f (1 - \sigma) \chi_f q_{t+1}]$ in Eq. 11. That is, $\chi_h > \chi_f$ and implies that there is a reduced incentive to accumulate durables for collateral because foreign lenders are less efficient than domestic lenders at recovering loans. It is also evident that the marginal benefit of durables purchased by borrowers depends on the proportion of the domestic loan-to-value ratio $\chi_h = 0.80$ to the foreign loan-to-value ratio $\chi_f = 0.40$ and whether the borrowing constraints are binding or not. As borrowers reallocate the purchase of durables from the domestic to the foreign market and vice versa, the collateral constraint is relaxed.

3.3 The effects of an international bond shock

Figure 3 shows the impulse response functions (IRFs) of non-durables, durables, the relative price of durables, the user cost of durables, and domestic debt in the face of an international bond shock. The restrictions are the same as those in Figure 1. In the IRFs, the unbroken (green) line shows the reaction of the SOE-SP model when non-durables have sticky prices and durables have

flexible prices. The figure shows a decrease in both consumption of non-durables and consumption of durables. Decreases in consumption of durables are steeper than those of consumption of non-durables. Whereas the relative price of durables increases at an almost unitary rate, the user cost of durables increases up to lag six before converging to zero. Domestic debt, on the other hand, decreases monotonically with decreases in consumption of durables. The broken (blue) line shows the reaction of the SOE-SP model when durables have sticky prices and non-durables have flexible prices. It reveals an increase in the consumption of both non-durables and durables. Further, the increase in the consumption of durables is larger than the increase in the consumption of non-durables. The relative price of durables decreases while the user cost of durables increases. Domestic debt, on the other hand, increases sharply before declining to zero in the ninth period. The spiky (red) line shows the reaction to equally sticky consumption of non-durables and durables.

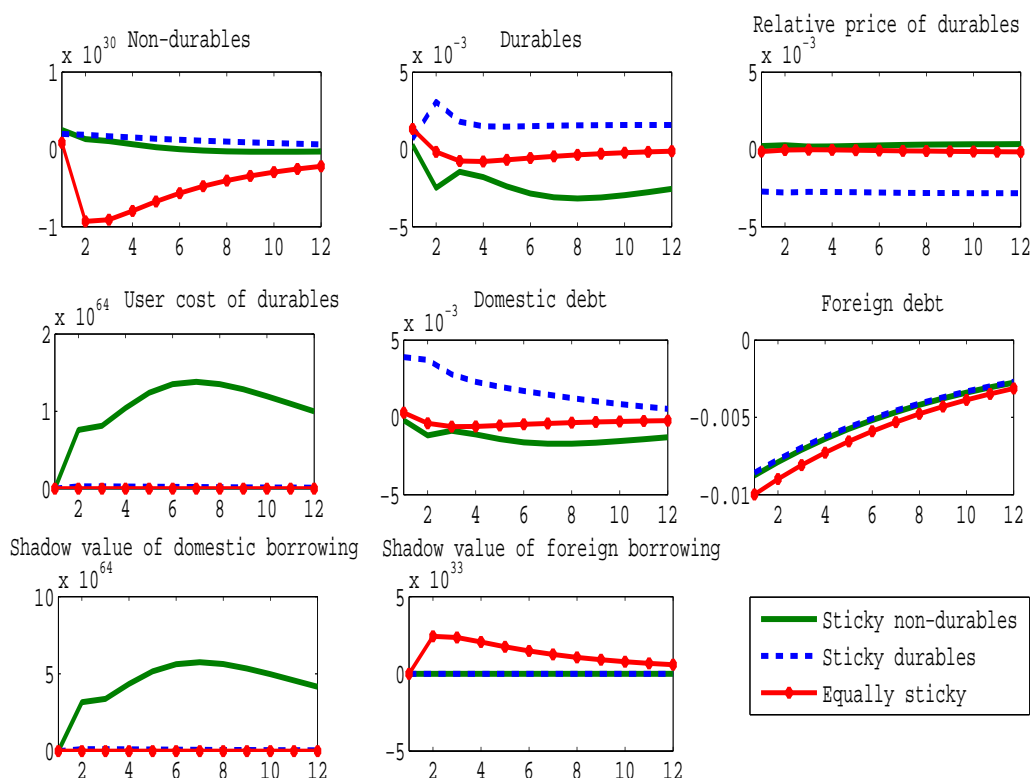


Figure 3: Impulse responses to an international bond shock: effect of varying the degree of stickiness

It is evident from the figure that there is a decrease in the consumption of both non-durables and durables, with the decline in the former being steeper than in the latter. Whereas the relative price of durables and the domestic debt level decrease in the face of an international bond shock, the user cost of durables increases at an almost unitary rate.

4 Conclusion

This paper has simulated an small open economy sticky price (SOE-SP) model calibrated to the South African economy. It shows that introducing borrowing and lending constraints into a SOE-SP model, in the face of a foreign monetary policy tightening and an international bond shock, partially solves the co-movement puzzle. In particular, sticky durables and sticky non-durables help the SOE-SP model to mimic a decline in the relative price of durable goods observed in the data. That is, introducing credit frictions such as borrowing and lending constraints makes it possible to reconcile the sticky price model with the data.

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Appendix

This appendix recaps the full non-linear model.

Borrowers:

$$C_t + q_t (D_t - (1 - \delta)D_{t-1}) + R_{t-1}^h \frac{B_{t-1}^h}{\pi_{c,t}} + \Xi (FA_{t-1}) R_{t-1}^f \frac{e_t}{e_{t-1}} \frac{B_{t-1}^f}{\pi_{c,t}} = B_t^h + B_t^f + w_t N_t + \tau_t, \quad (\text{B.1})$$

$$R_t^h B_t^h \leq E_t (\sigma \chi_h q_{t+1} D_t), \quad (\text{B.2})$$

$$R_t^f B_t^f \leq E_t ((1 - \sigma) \chi_f q_{t+1} D_t), \quad (\text{B.3})$$

$$w_t = \frac{\nu}{\left[(1 - \alpha)^{\frac{1}{\eta}} + \alpha^{\frac{1}{\eta}} \right] \left[(1 - \omega)^{\frac{1}{1-\varkappa}} \right]} \frac{N_t^\varphi}{C_t}, \quad (\text{B.4})$$

$$\frac{1}{C_t} = \beta^t E_t \left(\frac{1}{C_{t+1}} \frac{R_t^h}{\pi_{c,t+1}} \right) + \lambda_t^h R_t^h, \quad (\text{B.5})$$

$$\frac{1}{\tilde{C}_t} = \beta^t E_t \left(\frac{1}{\tilde{C}_{t+1}} \Xi(F A_t) \frac{e_{t+1}}{e_t} \frac{R_t^f}{\pi_{c,t+1}} \right) + \lambda_t^f R_t^f, \quad (\text{B.6})$$

$$Z_t \equiv \frac{1}{q_t} \left\{ E_t \frac{\beta^t}{\tilde{C}_{t+1}} D_t q_{t+1} + D_t E_t \left[\lambda_t^h \sigma \chi_h q_{t+1} + \lambda_t^f (1 - \sigma) \chi_f q_{t+1} \right] \right\}. \quad (\text{B.7})$$

Savers:

$$\tilde{C}_t + q_t \left(\tilde{D}_t - (1 - \delta) \tilde{D}_{t-1} \right) + \tilde{B}_t^h = R_{t-1}^h \frac{\tilde{B}_{t-1}^h}{\pi_{c,t}} + w_t \tilde{N}_t + \tau_t, \quad (\text{B.8})$$

$$\tilde{B}_t^h \leq \hat{\sigma} \left(R_{t-1}^h \tilde{B}_{t-1}^h + q_t \tilde{D}_{t-1} \right), \quad (\text{B.9})$$

$$w_t = \frac{\nu}{\left[(1 - \alpha)^{\frac{1}{\eta}} + \alpha^{\frac{1}{\eta}} \right] (\omega)^{\frac{1}{1-\kappa}} \tilde{C}_t^{\varphi}}, \quad (\text{B.10})$$

$$\frac{1}{\tilde{C}_t} + \lambda_t' = \zeta^t E_t \left(\frac{1}{\tilde{C}_{t+1}} \frac{R_t^h}{\pi_{c,t+1}} \right) + \lambda_{t+1}' \hat{\sigma} R_t^h, \quad (\text{B.11})$$

$$\frac{1}{\tilde{C}_t} q_t = \frac{j}{\tilde{D}_t} + \zeta^t E_t \left(\frac{1}{\tilde{C}_{t+1}} q_{t+1} + \lambda_{t+1}' \hat{\sigma} q_{t+1} \right). \quad (\text{B.12})$$

Firms: Intermediate goods producers

$$\hat{\pi}_{c,t}^h = \zeta^t E_t \left(\hat{\pi}_{c,t+1}^h \right) + \frac{\varepsilon_c - 1}{v_c} \widehat{m} \widehat{c}_{c,t}, \quad (\text{B.13})$$

$$\hat{\pi}_{d,t}^h = \zeta^t E_t \left(\hat{\pi}_{d,t+1}^h \right) + \frac{\varepsilon_d - 1}{v_d} \widehat{m} \widehat{c}_{d,t}. \quad (\text{B.14.})$$

Market clearing conditions:

$$Y_{c,t} = \varsigma C_t + (1 - \varsigma) \tilde{C}_t + \frac{v_c}{2} (\pi_{c,t} - 1)^2 Y_{c,t}, \quad (\text{B.15})$$

$$Y_{d,t} = \varsigma (D_t - (1 - \delta) D_{t-1}) + (1 - \varsigma) \left[\left(\tilde{D}_t - (1 - \delta) \tilde{D}_{t-1} \right) \right] + \frac{v_d}{2} (\pi_{d,t} - 1)^2 Y_{d,t}. \quad (\text{B.16})$$

$$B_t^h = \tilde{B}_t^h, \quad (\text{B.17})$$

$$B_t^f = 0, \quad (\text{B.18})$$

$$\tau_t = 0. \quad (\text{B.19})$$

Definitions:

$$X_t = \left[(1 - \omega)^{\frac{1}{\varepsilon}} C_t^{\frac{\varepsilon-1}{\varepsilon}} + \omega^{\frac{1}{\varepsilon}} D_t^{\frac{\varepsilon-1}{\varepsilon}} \right]^{\frac{\varepsilon}{\varepsilon-1}}, \quad (\text{B.20})$$

$$C_t \equiv \left[(1 - \alpha)^{\frac{1}{\eta}} C_{h,t}^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}} C_{f,t}^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}, \quad (\text{B.21})$$

$$P_t \equiv \left[(1 - \alpha) P_{h,t}^{1-\eta} + \alpha P_{f,t}^{1-\eta} \right]^{\frac{1}{1-\eta}}, \quad (\text{B.22})$$

$$\Xi (FA_{t-1}) \equiv (-\phi_{fa} FA_t), \quad (\text{B.23})$$

$$FA_t \equiv \frac{e_t B_t^f}{P_t^h}, \quad (\text{B.24})$$

$$q_t \equiv \frac{P_{d,t}}{P_{c,t}}, \quad (\text{B.25})$$

$$Y_{j,t}(i) = N_{j,t}(i), \quad (\text{B.26})$$

$$\Lambda_{j,t} \equiv \zeta E_t \left(\frac{\tilde{\lambda}_{t+1}}{\tilde{\lambda}_t} \right), \quad (\text{B.27})$$

$$D_t^{Share} = (1 - \omega) C_t, \quad (\text{B.28})$$

$$D_t^{Shadow} = (1 - \alpha) \frac{q_t}{C_t}, \quad (\text{B.29})$$

$$Y_t = Y_{c,t} + Y_{d,t}. \quad (\text{B.30})$$

Small open economy dynamics:

$$\pi_t = \pi_t^h \frac{\left(\alpha + (1 - \alpha) S_t^{1-\eta}\right)^{\frac{1}{1-\eta}}}{\left(\alpha + (1 - \alpha) S_{t-1}^{1-\eta}\right)^{\frac{1}{1-\eta}}}, \quad (\text{B.31})$$

$$e_t = \left[\alpha (S_t)^{\eta-1} + (1 - \alpha)\right]^{\frac{-1}{1-\eta}}, \quad (\text{B.32})$$

$$R_t^h = \Xi (FA) R_t^f. \quad (\text{B.33})$$

Exogenous AR(1) shock process:

$$B_t^f = \rho_B B_{t-1}^f - \epsilon_{B_t^f}, \quad (\text{B.34})$$

$$R_t^f = \rho_R R_{t-1}^f + \epsilon_{R_t^f}. \quad (\text{B.35})$$