Can Sticky Portfolios Explain International Capital Flows and Asset Prices?*

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May 18, 2021

Abstract

Over the past decade portfolio choice has become an important element of many DSGE open economy models. However, there is a substantial body of evidence that is inconsistent with standard frictionless portfolio choice models. In this paper we introduce a quadratic cost of changes in portfolio allocation into a two-country DSGE model. We investigate what level of portfolio frictions is most consistent with the data and the impact of portfolio frictions on asset prices and net capital flows. We find that the portfolio friction can account for (i) micro evidence of portfolio inertia by households, (ii) macro evidence of the price impact of financial shocks and related disconnect of asset prices from observed fundamentals, (iii) a broad set of moments related to the time series behavior of saving, investment and net capital flows, and (iv) phenomena such as excess return momentum, reversal and post-earnings announcement drift. For a plausible level of the friction, financial and saving shocks each account for close to half of the variance of net capital flows.

1 Introduction

Portfolio allocation decisions naturally affect both asset prices and capital flows. But apart from ad hoc models such as the Mundell-Fleming model and portfolio balance models, portfolio choice played a limited role in open economy models until about 2010. Gourinchas (2006) wrote: "Looking ahead, the next obvious step is to build general equilibrium models of international portfolio allocation with incomplete markets. I see this as a major task that will close a much needed gap in the literature...". Until that point in time, most models either assumed complete markets or trade in risk-free bonds.[1] This has changed significantly over the past decade, starting with the development of solution techniques for open economy DSGE models with portfolio choice.[2] However, the predictions of standard frictionless portfolio choice models have some features that are sharply at odds with the data. In this paper we introduce a portfolio adjustment cost, which generates model predictions that are more consistent with micro evidence of portfolio choice and macro evidence on the importance of financial shocks and features of asset price dynamics such as excess return momentum and reversal and post-earnings announcement drift. We then investigate the impact of this friction on asset prices and net capital flows.

A simple frictionless mean-variance two asset portfolio choice model implies

$$z_t = \frac{E_t(er_{t+1})}{\gamma var(er_{t+1})} \tag{1}$$

where the expected excess return is divided by the product of risk aversion and the variance of the excess return. All that matters is the expected excess return and risk over the next period. Past portfolio choice has no direct impact on current portfolio choice. Future expected returns and risk beyond the next period do not matter either. Moreover, the portfolio is very sensitive to changes in expected returns over the next period as the variance of the excess return tends to be small and all investors adjust their portfolio immediately.

These features contrast with the micro evidence on portfolio choice. First, a substantial number of papers have documented portfolio inertia of households.[3] Based on a survey of US households that hold equity or equity mutual funds, the Investment Company Institute reports that about 60 percent make no change to their stock or mutual fund portfolio during any particular year.[4] Even less frequent portfolio changes apply to retirement accounts. The

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[1]Models with trade in bonds usually allow agents to hold claims on domestic capital as well, but portfolio choice is typically removed through linearization that implies zero expected excess returns.

[2]See for example Devereux and Sutherland (2007,2010), Tille and van Wincoop (2010,2014) and Evans and Hnatkovska (2012,2014).

[3]See for example Ameriks and Zeldes (2004), Bilias et al. (2010), Brunnermeier and Nagel (2008), Mitchell et al. (2006).

[4]In the year 2001, 60 percent made no change (see Equity Ownership of America, 2002). In 2007, 57

Investment Company Institute (2021) reports that for over 30 million employer-based defined contribution retirement plans, 90 percent of investors made no changes over a given year to allocations of their account balances from 2010 to 2020 (Investment Company Institute, 2021).[5] Giglio et al. (2021) consider the portfolio and expected returns of US-based Vanguard investors. They find not only that investors change their portfolios infrequently, but that the responsiveness to expected returns is much weaker than implied by (1) for a plausible rate of risk-aversion. Finally, in the international context Bacchetta, Tièche and van Wincoop (2020) find that US equity mutual funds face significant costs to portfolio adjustment that lead to both portfolio inertia and a weak portfolio response to expected returns.[6]

At the macro level, a frictionless portfolio model like (1) implies that financial shocks have little effect on asset prices. A financial shock is a latent asset demand or portfolio shock. Since portfolios are so sensitive to expected excess returns, a very small change in the expected excess return is sufficient to clear the market, implying a very small price impact of financial shocks. Gabaix and Koijen (2020) use granular IV to show that financial shocks have a large impact on equity prices, about a factor 100 larger than implied by frictionless models. Related to this, there is evidence that financial shocks are the dominant driver of asset prices. This is the main message of Itskhoki and Muhkin (2021) for the foreign exchange market, who argue that exchange rates are largely driven by financial shocks, accounting for the disconnect from macro fundamentals. Similarly, Koijen and Yogo (2019) document that latent asset demand shocks are the main driver of equity prices.

Frictionless models also have a hard time accounting for asset prices dynamics such as momentum and reversal in excess returns that is documented in a large literature. Specifically, excess returns are positively correlated with their own lag up to about 12 months (momentum), while they are negatively autocorrelated for longer lags (reversal). Closely related is the phenomenon of post-earnings announcement drift, where equity prices continue to rise for several months or quarters subsequent to positive earnings news.

We introduce a quadratic portfolio adjustment cost into a two country DSGE model. Gârleanu and Pedersen (2013) analyze this type of friction in a partial equilibrium portfolio choice model. Bacchetta and van Wincoop (2021) use it in a model with short-term and long-term bonds to account for exchange rate puzzles, while Bacchetta, Tièche, and van Wincoop (2021) apply it to the equity market.[7]

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percent made no change (see Equity and Bond Ownership in America, 2008). This is based on equity holdings either as part of or outside an employer-sponsored retirement plan.

[5]Similarly, Mitchell et al. (2006) find that 80 percent of 1.2 million workers with 401(k) plans initiated no trades over a two-year period.

[6]Related to that, Bohn and Tesar (1996) and Froot et al. (2001) find that international portfolio flows are highly persistent and strongly related to lagged returns.

[7]In a closed economy, Bonaparte et al. (2012) examine the implications of quadratic portfolio adjustment costs for equity only.

A quadratic portfolio adjustment cost changes the frictionless portfolio (1) in two important ways, one backward looking and one forward looking. First, the optimal portfolio will not just depend on expected returns, but also on last period's portfolio. This gradual portfolio adjustment is consistent with evidence of portfolio inertia exhibited by households and mutual funds. Second, the optimal portfolio depends not just on the expected excess return over the next period, but the present value of all future expected excess returns. These backward and forward looking features of the optimal portfolio have several implications. First, they imply that the portfolio is much less sensitive to the expected excess return over the near future, leading to a significantly larger price impact of financial shocks. Second, the gradual portfolio adjustment generates features such as excess return momentum and reversal, and post-earnings announcement drift as a humped shaped portfolio response to shocks is reflected in asset prices.[8]

Besides the quadratic portfolio costs, the model features infinitely-lived agents with broad claims on Home and Foreign capital. This contrasts with previous models with quadratic portfolio costs that have considered partial equilibrium models or focused on a particular asset market. It allows us to consider the implications for overall net capital flows, or the current account, by embedding the portfolio friction into a standard open economy DSGE model of saving and investment decisions. We assume Rince preferences (see Farmer, 1990), so that we can conveniently separate portfolio decisions from consumption decisions. We model financial shocks as exogenous tax shocks on foreign portfolio holdings. These shocks generate portfolio shifts by introducing an exogenous additive component to the portfolio expression.

Besides financial shocks, the model also has dividend shocks (productivity shocks and capital share shocks), saving shocks (time-discount rate shocks) and investment shocks (perturbation to a standard Tobin Q investment relationship). Both types of dividend shocks are needed as the volatility of profits (net operating surplus) cannot be accounted for by productivity shocks alone. Saving and investment shocks are needed to account for the observed volatility of saving and investment rates in the data. We also make sure that there is a realistic relationship between asset prices and saving and investment rates.

We consider both the level of the portfolio friction that is most consistent with the data and the impact of a change in the friction on the relative asset price and net capital flows. For the former exercise we adjust some other parameters to target key moments, such as the volatility of the saving rate, investment rate and excess return. The model is most consistent with the data for an intermediate level of the financial friction that is reasonable in light of portfolio inertia at the household level. Financial shocks are then the main driver of the

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[8]Another implication is the predictability of excess returns, as shown in Bacchetta and van Wincoop (2021) for exchange rates. We will not focus on this aspect in this paper.

relative asset price, consistent with the literature. Net capital flows are about equally driven by financial shocks and saving shocks.

When the friction is too high, the autocorrelation of the excess return becomes too high as a result of the gradual portfolio adjustment that leads to a gradual asset price change in response to some shocks. In other words, there is too much excess return momentum. When there is no friction, the size of the financial shock that is needed to target key moments (particularly the volatility of the excess return) becomes enormous. This is due to a very small price impact of financial shocks. For a more reasonable size of financial shocks, excess return volatility is much too low and the relative asset price is largely driven by dividends. This contrasts with evidence that asset prices are largely driven by financial shocks. The frictionless case also does not produce any excess return momentum and reversal. There is also no post-earnings announcement drift.

We find that a higher portfolio friction, holding other parameters constant, raises the impact of financial and saving shocks on the relative asset price, while it weakens the price impact of shocks that affect dividends (productivity shocks, capital share shocks and investment shocks). A higher friction increases the response of net capital flows to financial shocks and shocks that affect dividends, while it has little effect on the response of net capital flows to a saving shock.

Besides a portfolio adjustment cost, there are two alternative ways of modeling sticky portfolios. A common approach in the finance literature is to assume that investors change their portfolios infrequently at fixed intervals in an overlapping manner.[9] It is also possible to assume a constant probability of changing portfolio shares, as in Bacchetta, Young, and van Wincoop (2020). While the three approaches differ in their details, they imply similar linearized portfolio expressions and similar asset price dynamics. The similarity of modeling approaches for portfolio stickiness is akin to the three approaches for price stickiness: Calvo pricing with a fixed probability of adjusting prices; staggered Taylor contracts; or Rotemberg adjustment costs. The approach in this paper is similar to the Rotemberg approach and is the most tractable in a DSGE model.

As discussed, one of the problems with the frictionless portfolio model is the significant sensitivity of the portfolio to expected returns. Making portfolios less sensitive to expected returns will increase the price impact of financial shocks. Portfolio frictions are not the only way to accomplish this. Alternatives are models that raise the effective rate of risk aversion or perceived risk. The former is the case in models with segmented markets[10], where a limited

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[9]See Lynch (1996), Gabaix and Laibson (2002), Abel et. al (2007), Bacchetta and van Wincoop (2010), Bogousslavsky (2016), Duffie (2010), Chien et al. (2012), Greenwood et al. (2018) or Hendershott et al. (2013).

[10]See for example Gabaix and Maggiori (2015), Gourinchas et al. (2020), Greenwood et al. (2020) and Itskhoki and Muhkin (2021).

number of arbitrageurs bear most of the risk, or in models where there is a cost to deviate from a certain level of asset holdings (e.g. Schmidt-Grohé and Uribe (2003)).[11] Models with long-term risk or disaster risk, as in Dou and Verdelhan (2015), have a similar implication as well. All raise the denominator of (1), making portfolios less sensitive to expected returns. But these assumptions do not generate the forward and backward looking aspects that a model with portfolio frictions does, which generate gradual portfolio adjustment to shocks and therefore asset price dynamics such as momentum and reversal.

The remainder of the paper is organized as follows. Section 2 presents the model. Section 3 describes the data and calibration procedure. The two countries in the calibration are the US and the aggregate of the other G7 countries. Section 4 discusses the results. We also consider an extension where there is a cost of deviating from the buy-and-hold portfolio instead of the lagged portfolio. In that case there is a cost to any asset trade, even trade associated with portfolio rebalancing. Section 5 concludes.

2   Model Description

We introduce costly portfolio adjustment in a one-good, two-country model of saving and investment. The two countries are Home and Foreign and there are two assets. We assume two types of agents. Investors hold the two assets and make saving and portfolio decisions. Households earn labor income and are simply hand to mouth.

2.1   Portfolio and Consumption Problem

The assets are claims on capital of both countries, with returns $R_{H,t+1}$ and $R_{F,t+1}$. Investors allocate their wealth between these two assets.[12] Portfolio shares of Home investors in the Home and Foreign assets are $z_{H,t}$ and $1 - z_{H,t}$, while Foreign shares are $z_{F,t}$ and $1 - z_{F,t}$. The main assumption in this paper is that it is costly for investors to change these shares. This key friction leads to more gradual portfolio adjustment to changes in expected returns.

More precisely, we assume a quadratic adjustment cost $0.5\psi(z_{h,t} - z_{h,t-1})^2$ for country h that reduces welfare.[13] The parameter ψ determines the size of this portfolio friction. These costs are associated with the decision process of choosing portfolio shares. They are not transaction costs as investors can partly rebalance their portfolios. We will also examine the case where rebalancing is costly by assuming a quadratic cost of deviating from the buy-and-hold portfolio.

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[11]Yakin (2020) shows that these have similar implications.

[12]Adding internationally traded bonds in fixed supply has little impact on the analysis.

[13]It is technically more convenient to assume that this cost affects directly utility, rather than reduce resources in the budget constraint.

We focus the analysis on the average portfolio share in the Home asset: $z_t^A = 0.5(z_{H,t} + z_{F,t})$. Changes in this average share affect net capital flows. Holding z_t^A fixed, changes in $z_t^D = z_{H,t} - z_{F,t}$ (a measure of home bias) only affect gross capital flows, not net capital flows.

We assume that investors have Rince preferences. This implies that the intertemporal elasticity of substitution is 1, so that the optimal consumption-wealth ratio solely depends on the time discount rate, while the rate of risk-aversion γ is a separate parameter that is important for portfolio choice. The time discount rate, denoted $\beta_{h,t}$ for country h, is allowed to vary over time and gives rise to saving shocks. The Bellman equation for investors from country h is

$$\ln(V_{h,t}) = \max_{C_{h,t}, z_{h,t}} \left\{ (1 - \beta_{h,t}) \ln(C_{n,t}) + \beta_{h,t} \left[\ln \left(\left[E_t(V_{h,t+1})^{1-\gamma} \right]^{\frac{1}{1-\gamma}} \right) - 0.5 \psi (z_{h,t} - z_{h,t-1})^2 \right] \right\}$$

(2)

The last term captures the cost of changing portfolio shares.

2.2 Budget Constraints and Financial Shocks

The financial wealth of investors from country h, $W_{h,t+1}$, evolves according to

$$W_{h,t+1} = R_{t+1}^{p,h} (W_{h,t} - C_{h,t})$$

(3)

where $R_{t+1}^{p,h}$ is the portfolio return. Investors start period t with financial wealth $W_{h,t}$. They consume $C_{h,t}$ and invest the remainder in the two assets, on which they earn a return $R_{t+1}^{p,h}$ from t to $t+1$. The portfolio return for Home and Foreign investors is

$$R_{t+1}^{p,H} = z_{H,t} R_{H,t+1} + (1 - z_{H,t}) e^{-\tau_{H,t}} R_{F,t+1} + T_{H,t+1}$$

(4)

$$R_{t+1}^{p,F} = z_{F,t} e^{-\tau_{F,t}} R_{H,t+1} + (1 - z_{F,t}) R_{F,t+1} + T_{F,t+1}$$

(5)

For Home investors, $\tau_{H,t}$ is a tax on the Foreign asset return. For Foreign investors, $\tau_{F,t}$ is a tax on the Home asset return. These play two roles in the model. First, their mean τ can be calibrated to generate realistic home bias. Second, time variation in $\tau_t^D = \tau_{H,t} - \tau_{F,t}$ generates exogenous portfolio shifts between Home and Foreign assets, which we will refer to as financial shocks. Finally, the terms $T_{H,t+1}$ and $T_{F,t+1}$ are lump sum redistributions of the aggregate portfolio taxes back to the investors. Agents take these as given, so they do not affect portfolio choice. This means that in the aggregate

$$R_{t+1}^{p,H} = z_{H,t} R_{H,t+1} + (1 - z_{H,t}) R_{F,t+1}$$

(6)

$$R_{t+1}^{p,F} = z_{F,t} R_{H,t+1} + (1 - z_{F,t}) R_{F,t+1}$$

(7)

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as if there were no taxes.

2.3 Optimal Portfolios

Investors maximize the right-hand side of (2) subject to the wealth accumulation equation (3) and portfolio return, (4) or (5). Consumption and portfolio Euler equations are derived in Appendix A, where we follow an approximation approach similar to Campbell and Viceira (1999) to obtain an explicit portfolio expression. The solution is as follows. The consumption-wealth ratio is always 1 minus the discount rate:

$$C_{h,t} = (1 - \beta_{h,t})W_{h,t} \tag{8}$$

Let $r_{H,t+1}$ and $r_{F,t+1}$ be the log Home and Foreign returns and $er_{t+1} = r_{H,t+1} - r_{F,t+1}$ the excess return. The portfolio Euler equations then lead to the following second-order difference equations in portfolio shares:

$$\beta\psi E_t z_{H,t+1} - \left(\gamma\sigma^2 + \psi(1+\beta)\right) z_{H,t} + \psi z_{H,t-1} + E_t er_{t+1} + \tau_{H,t} + \nu_H = 0 \tag{9}$$

$$\beta\psi E_t z_{F,t+1} - \left(\gamma\sigma^2 + \psi(1+\beta)\right) z_{F,t} + \psi z_{F,t-1} + E_t er_{t+1} - \tau_{F,t} + \nu_F = 0 \tag{10}$$

Here β is the steady state time discount rate, σ^2 is the variance of the excess return and ν_H, ν_F are hedge terms that depend on second moments that we treat as constants (see Appendix A).

Using (9)-(10), the expression of the average portfolio is (ignoring the constants)

$$\beta\psi E_t z_{t+1}^A - \left(\gamma\sigma^2 + \psi(1+\beta)\right) z_t^A + \psi z_{t-1}^A + E_t er_{t+1} + 0.5\tau_t^D = 0 \tag{11}$$

We will use this second-order difference equation of the average portfolio share to solve the model, together with the other linearized equations of the model. But to gain intuition, it is useful to solve the difference equation in order to get an explicit expression for the portfolio share:

$$z_t^A = \eta z_{t-1}^A + \frac{\eta}{\psi} \sum_{s=1}^{\infty} (\beta\eta)^{s-1} E_t(er_{t+s}) + 0.5\lambda\tau_t^D \tag{12}$$

where

$$\eta = \frac{\gamma\sigma^2 + \beta(1+\psi) - \sqrt{(\gamma\sigma^2 + \beta(1+\psi))^2 - 4\beta\psi^2}}{2\beta\psi}$$

$$\lambda = \frac{\eta}{\psi}\frac{1}{1 - \rho_\tau\beta\eta}$$

Here we have assumed that τ_t^D follows an AR process with AR coefficient ρ_τ.

The portfolio solution (12) has three terms. The first term shows that the optimal portfolio share depends on the lagged portfolio share with a coefficient η. The weight η on the lagged portfolio depends positively on the portfolio friction ψ. η is zero when ψ is zero and approaches 1 as $\psi \to \infty$. The second term shows that the optimal portfolio depends on the present discounted value of all future expected excess returns. When $\psi = 0$, agents only respond to the expected excess return over the next period, $E_t er_{t+1}$. As a result of the portfolio friction, agents adjust their portfolio today to changes in the expected excess return beyond the next period as they wish to smooth portfolio changes over time. The discount rate is $\beta \eta$, which implies a higher weight on expected excess returns further into the future when ψ is larger.

Finally, the last term in (12) is related to financial shocks. A rise in τ_t^D will lead to a portfolio shift from the Foreign to the Home asset. Define

$$f_t = \lambda \tau_t^D \tag{13}$$

Δf_t is the total flow from the Foreign to the Home asset associated with changes in τ_t^D, measured as a fraction of market value of either asset. To see this, we have $\Delta z_{H,t} + \Delta z_{F,t} = 2\Delta z_t^A = \lambda \Delta \tau_t^D = \Delta f_t$. This is the sum of the increase in demand for the Home asset by investors from both countries as a fraction of their financial wealth, which in steady state is equal to the value of both asset markets. We will measure the price impact of financial shocks as the instantaneous increase in the relative log asset price, $q_t^D = q_{H,t} - q_{F,t}$ relative to Δf_t at the time of a shock to τ_t^D. It tells us the percentage change in the relative price in response to a 1 percent increase in demand for the Home asset. This price impact parameter is called M:

$$M = \frac{\Delta q_t^D}{\Delta f_t} \tag{14}$$

2.4 Asset Returns and Investment

The assets are claims on capital of both countries, with prices of respectively $Q_{H,t}$ and $Q_{F,t}$ in the Home and Foreign country. The gross return in country $h = H, F$ from t to $t+1$ is

$$R_{h,t+1} = \frac{\Pi_{h,t+1}/K_{h,t+1} + (1-\delta)Q_{h,t+1}}{Q_{h,t}} \tag{15}$$

Here $\Pi_{h,t+1}/K_{h,t+1}$ is profits per unit of capital and δ is the rate of depreciation of capital:

$$K_{h,t+1} = (1-\delta)K_{h,t} + I_{h,t} \tag{16}$$

where $I_{h,t}$ is investment.

Output is Cobb Douglas:

$$Y_{h,t} = A_{h,t} K_{h,t}^{\theta_{h,t}} N_{h,t}^{1-\theta_{h,t}} \tag{17}$$

We allow for shocks to both productivity and the capital share, allowing profits to be more volatile than output as in the data. Workers receive a fraction $1 - \theta_{h,t}$ of output, which they consume. The rest goes to profits of the shareholders:

$$\frac{\Pi_{h,t+1}}{K_{h,t+1}} = \theta_{h,t+1} A_{h,t+1} K_{h,t+1}^{\theta_{h,t+1}-1} + \frac{\pi_{h,t+1}}{K_{h,t+1}} \tag{18}$$

Here we have assumed that the labor supply is fixed at 1. The term $\pi_{h,t+1}$ is profits of installment firms at time t, which investors get as well.

Producing $I_{h,t}$ capital goods requires

$$e^{m_{h,t}}(I_{h,t} - \delta K_{h,t}) + \delta K_{h,t} + 0.5\zeta \frac{1}{K_{h,t}}(I_{h,t} - \delta K_{h,t})^2 \tag{19}$$

consumption goods. Installment firms at time t then maximize profits

$$\pi_{h,t} = Q_{h,t} I_{h,t} - e^{m_{h,t}}(I_{h,t} - \delta K_{h,t}) - \delta K_{h,t} - 0.5\zeta \frac{1}{K_{h,t}}(I_{h,t} - \delta K_{h,t})^2 \tag{20}$$

Optimal investment takes the familiar Tobin Q form:

$$\frac{I_{h,t}}{K_{h,t}} = \delta + \frac{1}{\zeta}(Q_{h,t} - e^{m_{h,t}}) \tag{21}$$

The random variable $m_{h,t}$ captures exogenous investment shocks.

Substituting (21) back into (20), we obtain an expression for $\pi_{h,t}$. Using this, the gross return on the asset of country h can be written as

$$R_{h,t+1} = \frac{D_{h,t+1} + Q_{h,t+1}}{Q_{h,t}} \tag{22}$$

where the dividend $D_{h,t+1}$ is

$$D_{h,t+1} = \theta_{h,t+1} A_{h,t+1} K_{h,t+1}^{\theta_{h,t+1}-1} - \delta + \frac{1}{2\zeta}(Q_{h,t+1} - e^{m_{h,t+1}})^2 \tag{23}$$

The last term will drop out after linearization, so that the dividend is equal to the marginal product of capital net of depreciation.

2.5 Market Clearing Conditions

Investors in country h start period t with wealth $W_{h,t}$, of which they consume a fraction $1 - \beta_{h,t}$. They therefore invest $\beta_{h,t} W_{h,t}$ in the two assets. The two asset market clearing conditions are then

$$\beta_{H,t} W_{H,t} z_{H,t} + \beta_{F,t} W_{F,t} z_{F,t} = Q_{H,t} K_{H,t+1} \tag{24}$$

$$\beta_{H,t} W_{H,t} (1 - z_{H,t}) + \beta_{F,t} W_{F,t} (1 - z_{F,t}) = Q_{F,t} K_{F,t+1} \tag{25}$$

2.6 Shocks

Since the objective is to match quantitatively various aspects of the data, we introduce four types of shocks: dividend, saving, investment, and financial shocks. The need for dividend shocks is clear as these are the payoffs of the assets. The introduction has already discussed the importance of financial shocks. There are several reasons for introducing saving and investment shocks. Without these shocks, saving and investment will generally be much less volatile than in the data. Moreover, relative saving and investment would be too closely tied to the relative log asset price q_t^D. As discussed further below, relative investment would be a linear function of q_t^D, while relative saving would a linear function of $q_t^D - d_t^D$, where d_t^D is the relative log dividend.

Dividend shocks are related to both productivity and capital share shocks. Assume $A_{h,t} = \bar{A} e^{a_{h,t}}$, where $\bar{A}$ is the steady state value of productivity. We introduce average and relative shocks, defining in all cases $x_t^A = 0.5(x_{H,t} + x_{F,t})$ and $x_t^D = x_{H,t} - x_{F,t}$. For average and relative productivity shocks we then have

$$a_{t+1}^A = \rho_a a_t^A + \epsilon_{t+1}^{A,a} \tag{26}$$

$$a_{t+1}^D = \rho_a a_t^D + \epsilon_{t+1}^{D,a} \tag{27}$$

The two innovations have standard deviations of respectively $\sigma_{A,a}$ and $\sigma_{D,a}$ and are uncorrelated.

Analogously, for capital share shocks we have

$$\theta_{t+1}^A - \theta = \rho_\theta \left(\theta_t^A - \theta \right) + \epsilon_{t+1}^{A,\theta} \tag{28}$$

$$\theta_{t+1}^D = \rho_\theta \theta_t^D + \epsilon_{t+1}^{D,\theta} \tag{29}$$

where θ is the mean. The two innovations have standard deviations of respectively $\sigma_{A,\theta}$ and $\sigma_{D,\theta}$ and are uncorrelated.

To see how these shocks together affect dividends, the log-linearized dividend (see Ap-

pendix B) is

$$d_{h,t} = \frac{1 - \beta + \delta\beta}{1 - \beta} \left(a_{h,t} + \frac{1}{\theta}\theta_{h,t} + (\theta - 1)k_{h,t} \right) \tag{30}$$

where $k_{h,t}$ is the log capital stock.

Saving shocks are associated with changes in the time discount rate. We have

$$\beta_{t+1}^A - \beta = \rho_\beta \left(\beta_t^A - \beta \right) + \epsilon_{t+1}^{A,\beta} \tag{31}$$

$$\beta_{t+1}^D = \rho_\beta \beta_t^D + \epsilon_{t+1}^{D,\beta} \tag{32}$$

The two innovations have standard deviations of respectively $\sigma_{A,\beta}$ and $\sigma_{D,\beta}$ and are uncorrelated.

Investment shocks are shocks to the Tobin-Q relationship (21):

$$m_{t+1}^A = \rho_m m_t^A + \epsilon_{t+1}^{A,m} \tag{33}$$

$$m_{t+1}^D = \rho_m m_t^D + \epsilon_{t+1}^{D,m} \tag{34}$$

The shocks have standard deviations of respectively $\sigma_{A,m}$ and $\sigma_{D,m}$ and are uncorrelated.

Finally, financial shocks are given by

$$\tau_{t+1}^D = \rho_\tau \tau_t^D + \epsilon_{t+1}^\tau \tag{35}$$

The standard deviation of the shock is σ_τ. We do not introduce shocks to τ_t^A as such shocks do not affect net capital flows or any of the other variables of interest. They only affect gross capital flows. We assume that all shocks in the model are mutually uncorrelated.

2.7 Equilibrium

With the exception of portfolio Euler equations, we linearize around the deterministic steady state. Since a deterministic steady state does not exist for portfolios, we use an approach analogous to Campbell and Viceira (1999) to obtain the linear optimal portfolio expressions (9)-(10). Appendix B derives the full log-linearized system of equations.[14]

One can consider two sets of equations. One set involves differences of variables, jointly with z_t^A. The second set involves averages of variables, jointly with z_t^D. The system in averages is easy to solve by hand and leads to the solution for the average log asset price q_t^A

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[14]There is an ergodic distribution for relative wealth in this linearized system, even though we do not introduce features such as Uzawa preferences or finite lives. To see this, consider what happens when Home wealth is larger than Foreign wealth. As a result of home bias, this raises relative demand for Home assets. This raises the relative Home capital stock and asset price, which lowers the expected excess return on the Home asset. This in turn reduces the expected future portfolio return of Home relative to Foreign investors and therefore relative Home wealth.

discussed in Appendix B. The system in differences is more involved and leads to a solution for the relative log asset price q_t^D as a function of the following state variables:

$$\mathbf{S}_t = \left(q_{t-1}^D, w_{t-1}^D, k_{t-1}^D, \tau_t^D, \theta_t^D, a_t^D, \beta_t^D, \beta_{t-1}^D, m_t^D, m_{t-1}^D\right)' \tag{36}$$

We discuss this system in differences and solution in more detail in the Online Appendix.

One of the parameters of the model, the variance σ^2 of the excess return, is endogenous. We solve the model for a given σ, which enters the portfolio expressions, and then solve a fixed-point problem that equates the assumed σ to that implied by the equilibrium of the model.

2.8   Saving, Investment and Net Capital Flows

The current account equals net saving minus net investment: $CA_{h,t} = S_{h,t}^{net} - I_{h,t}^{net}$. This can also be written in terms of relative saving and investment. Omitting the country subscript, the current account of the Home country is $CA_t = 0.5S_t^{D,net} - 0.5I_t^{D,net}$. In equilibrium this must be equal to net capital outflows of the Home country, which we denote as NF_t. The equation $CA_t = NF_t$ can be thought of as an equilibrium equation that determines the relative asset price q_t^D. The difference between the two market clearing conditions (24) and (25) leads to the same equation, but writing it as $CA_t = NF_t$ helps provide intuition.

Appendix C shows that relative net saving is equal to

$$S_t^{D,net} = \frac{\beta_t^D}{\beta} + (1 - \beta)(2\bar{z} - 1)\left(d_t^D - q_t^D\right) \tag{37}$$

Here $\bar{z}$ is the steady state share invested domestically and $d_t^D = d_{H,t} - d_{F,t}$ is the relative log dividend.

Relative net investment is

$$I_t^{D,net} = \frac{1}{\zeta}\left(q_t^D - m_t^D\right) \tag{38}$$

The current account is a negative function of q_t^D: a rise in q_t^D raises relative Home investment through the Tobin-Q relationship, while lowering relative Home saving. To understand the latter, a rise in q_t^D raises relative Home wealth as long as there is home bias ($\bar{z} > 0.5$). This raises relative Home consumption and therefore lowers relative Home saving.

Net capital outflows can be written as

$$NF_t = -2\Delta z_t^A + 2\bar{z}(1 - \bar{z})\Delta q_t^D + (1 - \bar{z})S_t^{D,net} \tag{39}$$

The three terms on the right determine net capital outflows from a portfolio perspective. The first term is related to portfolio reallocation. An increase in the share allocated to

Foreign assets, which implies $\Delta z_t^A < 0$, leads to capital outflows. The second term relates to portfolio rebalancing. A higher relative price of the Home asset leads to a net purchase of Foreign assets for portfolio balancing reasons, implying net capital outflows. Finally, the last term is a portfolio growth term. Higher relative Home saving raises capital outflows relative to inflows associated with portfolio growth. A higher relative Home price will usually raise the first two terms, while slightly lowering the last. It tends to lower the expected excess return on the Home asset, lowering z_t^A. It also raises net outflows due to rebalancing.

Consider a shock that for unchanged q_t^D implies $CA_t > NF_t$, such as a positive saving shock or a negative investment shock, which increases CA_t, or a financial shock that leads to a portfolio shift towards the Home asset, which decreases NF_t. An increase in q_t^D then re-establishes equilibrium through several channels: lower relative saving, higher relative investment (both lowering CA_t), a higher expected excess return on the Foreign asset and portfolio rebalancing towards the Foreign asset (both raising NF_t). The impact of shocks on net capital flows will depend on the relative importance of these adjustment mechanisms, especially on the sensitivity of net capital outflows NF_t to q_t^D relative to the sensitivity of the current account CA_t to q_t^D.

3 Data and Calibration

3.1 Data

We use quarterly data from 1980 through 2018 to compute data moments and calibrate parameters. The Home country is the United States, while the Foreign country is a GDP-weighted average of the remaining G7 countries. For real GDP, net saving, and net investment we use OECD Quarterly National Accounts data. Net saving and net investment are not available at the quarterly frequency for all non-US G7 countries, so we compute the volatility and autocorrelations of saving and investment only for the US. As discussed below, for the calibration of one parameter we use both Home and Foreign net saving and investment rates, for which we use annual data from the OECD Annual National Accounts. The current account is the US current account from the IMF Balance of Payment Statistics and is scaled by GDP from the OECD Quarterly National Accounts.

As in the model, dividends are defined as profits divided by the capital stock. Using OECD Quarterly National Accounts data, we construct the profit measure as net operating surplus plus the capital share of mixed income.[15] A quarterly capital stock measure is

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[15]Mixed income is an income flow to proprietors that includes both capital and labor income. As in Cooley and Prescott (1995) and Gomme and Rupert (2007), we assume the labor share of mixed income is equal to the share of employee compensation in unambiguous capital and labor income, that is, employee compensation plus gross operating surplus. Details can be found in the Online Appendix, Section C.

obtained by combining annual capital stock data from Penn World Table 10.0 with the quarterly gross investment series from the OECD Quarterly National Accounts, assuming a quarterly depreciation rate of 0.015. Given data limitations for our profit measure, we use a shorter quarterly dataset from 1995 to 2018 for the US and the non-US G7.[16] These same data are also used to calibrate the processes for the capital share and productivity. The capital share is profits as defined above, divided by GDP minus net production taxes. It is available from 1995 to 2018. The Solow residual is real GDP divided by $K_{h,t}^{\theta_{h,t}} N_{h,t}^{1-\theta_{h,t}}$, where $N_{h,t}$ is Total Employment from OECD Main Economic Indicators. The productivity series is available from 1980 to 2018.

We construct a measure of the excess return to compute its standard deviation σ and autocorrelation. The return to capital in our model is a broad return to productive capital. We first compute a weighted average of equity and corporate bond returns. Equity returns are computed from the quarterly change in MSCI Total Return Index in US dollars. Corporate bond quarterly holding period returns are computed using data on corporate bond yields from the Global Financial Database.[17] We weigh equity and bond returns by their respective shares of total market capitalization. Stock market capitalization is taken from the World Bank's Global Financial Development data. Corporate bond market capitalization is the total amount outstanding from non-financial corporate and non-corporate issuers from the Bank of International Settlements Debt Securities Statistics.

Based on US Flow of Funds data from 1980 to 2018, we find that equity and corporate bonds account on average for 51 percent of the liabilities of non-financial corporations and non-corporations. The remainder are mostly safe assets such as bank loans and trade payables, for which the interest rate is known in advance. In order to reflect this in our broader return measure, we therefore approximate σ as the standard deviation of the excess return based on equity plus corporate bonds, scaled down by a factor 0.51. Further details regarding the data can be found in Online Appendix C.

3.2 Calibration

Some parameters are adopted from the literature, while others are based on direct measurement in the data or targeting moments in the data. While we conduct sensitivity analysis,

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[16]The OECD quarterly data report the sum of net operating surplus and mixed income. To attribute an appropriate share of mixed income to profits, we first use data from the OECD Annual National Accounts to obtain an estimate of the share that is mixed income. Then, we apply the share of mixed income to profits that is equal one minus the labor share outlined above (see the Online Appendix, Section C for details).

[17]As in Gourinchas and Rey (2007), we compute holding period returns from changes in bond yields using Eq. 10.1.19 in Campbell, Lo and MacKinlay (1997, p. 408), assuming that coupons are equal to yields and an average maturity of 10 years. The moments for the excess return measure were virtually identical using a zero coupon assumption with average duration of 10 years. See the Online Appendix, Section C for further details.

for most of the results risk-aversion γ is set at 10. It is adopted from Bacchetta and van Wincoop (2010), who use a model of gradual portfolio adjustment to account for the forward discount puzzle. The steady state time discount rate is set at $\beta = 0.99$, implying a 4 percent interest rate in the deterministic steady state. The mean capital share θ is set at 0.362, based on US data from 1980 to 2018 discussed above. The quarterly depreciation rate δ is set to 1.5 percent or 6 percent annually. This is computed using US data on consumption of fixed capital as a share of the capital stock.

The steady state portfolio share $\bar{z}$ invested domestically is technically not a parameter of the model, but the mean tax rate τ can be adjusted to obtain any $\bar{z}$. We calibrate it based on data from Bertaut and Tryon (2007), whose sample we extend from 1994 to 2015. One minus $\bar{z}$ is set equal to US external claims in stocks and bonds in the non-US G7, divided by total equity, debt and mutual fund assets of US households from the US Financial Accounts, averaged over quarterly data from 1994 through 2015.[18]

The AR coefficients ρ_a and ρ_θ of productivity and the capital share are based on data for the Solow residual and capital share discussed above. For productivity we first remove a linear trend. The AR coefficients are the average of those estimated for the US and non-US G7. Using the resulting innovations for the US and non-US G7, we compute the standard deviation of the average and relative innovations for productivity shocks and capital share shocks, $\sigma_{A,a}$, $\sigma_{D,a}$, $\sigma_{A,\theta}$ and $\sigma_{D,\theta}$.

The parameters σ_τ, ζ, $\sigma_{D,\beta}$, $\sigma_{D,m}/\zeta$, and $\sigma_{A,\beta}/\sigma_{D,\beta} = \sigma_{A,m}/\sigma_{D,m}$ are jointly set to match five moments in the data. Their values in Table 1 are based on $\psi = 1$, which we refer to as the benchmark. But we also consider $\psi = 0$ and $\psi = 3$ and these parameters will change as we vary ψ. The model moments are average moments over 1000 simulations over the same sample length as in the data. While the parameters are set jointly to target five moments, we have in mind a specific target moment for each parameter. The target moment for σ_τ is σ. As we will see, financial shocks are a dominant driver of the relative asset price and therefore the excess return. $\sigma_{D,\beta}$ is used to target the standard deviation of the saving rate.

A lower ζ and higher $\sigma_{D,m}/\zeta$ raise investment volatility, while higher values of both parameters reduce the explanatory power of Tobin's Q in investment volatility. We target them to match US investment volatility (I_t^{net}/Y_t) together with the R^2 of a regression of ΔI_t on Δq_t. In the data, the latter is based on Andrei, Mann and Moyen (2019) using aggregate US data for investment and Tobin's Q from 1975 to 2015. Tobin's Q can on average account for 25 percent of the variance of changes in the investment rate.

The ratios $\sigma_{A,\beta}/\sigma_{D,\beta}$ and $\sigma_{A,m}/\sigma_{D,m}$ are higher the more correlated saving and investment shocks are across countries. We use them to match $corr(\Delta[S_{H,t}/Y_{H,t}], \Delta[S_{F,t}/Y_{F,t}])$ and

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[18]To make the external claims to non-US G7 comparable to the total equity and debt portfolio of US residents (which includes non-G7 assets), we scale the claims on stocks and bonds in the non-US G7 by dividing by their share in total external claims in stock and bonds of the US.

$corr(\Delta[I_{H,t}/Y_{H,t}], \Delta[I_{F,t}/Y_{F,t}])$ in the data. Since we are unable to match both of these correlations exactly, and the saving and investment correlations are close to each other (respectively 0.42 and 0.47), we set $\sigma_{A,\beta}/\sigma_{D,\beta} = \sigma_{A,m}/\sigma_{D,m}$ to match the average of the cross-country correlations of changes in saving and investment rates. As discussed above, in both the data and model these are based on annual data from 1980 to 2018.

The AR coefficients ρ_β and ρ_m of saving and investment shocks are both set at 0.99. Setting them much lower leads to autocorrelations of saving and investment rates that are too low relative to the data. Finally, the AR coefficient ρ_τ of financial shocks is also set at 0.99. We will discuss higher and lower values as well in sensitivity analysis. The problem with less persistent financial shocks is that it can significantly reduce the price impact of financial shocks.

4   Results

We are interested in the impact of the portfolio friction, particularly on the relative asset price and net capital flows. We first address this by considering three values of ψ, while at the same time adjusting other parameters to match targeted moments, as discussed above.[19] This is intended to give each value of ψ the best chance, which allows us to address for what value of ψ the model is most consistent with the data. After that we consider the effect of changing the friction ψ while holding other parameters constant. This allows us to address the impact of the friction on the equilibrium relative price and net capital flows. In both cases we consider the implications for model moments, the impulse response of the relative price and net capital flows to shocks and the contribution of each of the shocks to the variance of the relative price and net capital flows.

We finish with some robustness analysis. We consider the results when the portfolio friction takes the form of a quadratic cost of deviating from the buy-and-hold portfolio instead of the lagged portfolio. This means that there is a cost to any asset trade, including trade associated with portfolio rebalancing. We also consider alternative assumptions about the rate of relative risk aversion and persistence of the financial shock.

4.1   Three Values of the Portfolio Friction

We present results for three values of the portfolio friction: $\psi = 0$, $\psi = 1$ and $\psi = 3$. In each case the parameters σ_τ, ζ, $\sigma_{D,\beta}$, $\sigma_{D,m}$ and $\sigma_{A,\beta}/\sigma_{D,\beta} = \sigma_{A,m}/\sigma_{D,m}$ are changed to target 5 moments, as discussed above. In computing the moments, we simulate the model 1000 times over 260 quarters. The moments are computed over the last 160 quarters,

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[19]Online Appendix D reports these other parameters for all cases that we consider.

corresponding to the data sample from 1980 to 2018. The parameters are chosen such that for the targeted moments the average of the model moments over the 1000 simulations matches the corresponding moments in the data.

4.1.1 Benchmark Case: $\psi = 1$

We first consider the benchmark case of $\psi = 1$, for which all parameters are shown in Table 1. To get some sense of how realistic this case is, in the portfolio solution (12) the weight on the lagged portfolio is $\eta = 0.92$. This is more meaningful if we relate it to a frequency p of portfolio adjustment. There is an analogy between a quadratic portfolio adjustment cost and a Calvo setup where investors change their portfolio with probability p. Bacchetta et al. (2021) obtain a similar portfolio expression to (12) when adopting the Calvo friction. Then the coefficient on the lagged portfolio is $1 - p$. For a quarterly frequency, this means that the probability of not making a new portfolio decision over an entire year is $(1 - p)^4$. With $1 - p = \eta = 0.92$, this means that approximately 70 percent of investors do not make a new portfolio decision during the course of one year. To put this in perspective, the Investment Company Institute reports that about 60 percent of US investors make no changes to their stock or mutual fund portfolio during any particular year.[20] This is not too far off from the 70 percent implied by $\psi = 1$, especially when taking into account that some of the reported transactions are for rebalancing purposes as opposed to a change in portfolio allocation.[21]

We first consider a set of moments implied by $\psi = 1$, shown in column (ii) of Table 2. Average model moments and the standard errors are shown, with targeted moments in italics. Data moments are shown in the first column. We consider standard deviations for five variables: excess return, saving rate, investment rate, net capital outflows (current account) as a fraction of GDP and relative output growth. Four autocorrelations are included: excess return, saving rate, investment rate and net capital outflows as a fraction of GDP. Four contemporaneous correlations are considered: the time series correlation between saving and investment rates, the correlation between the current account and output growth (cyclicality of the current account), the correlation between Home and Foreign asset price changes and between the relative asset price change and the relative dividend change.

The three "other" moments at the bottom of Table 2 are the R^2 of a regression of the change in the relative investment rate on the change in Tobin's Q, the size of a one standard deviation financial shock $(\sigma_\tau \lambda)$ and the parameter M that measures the price impact of financial shocks given in (14). No direct data measurement for the last two moments exists.

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[20]In the year 2001, 60 percent made no change (Equity Ownership of America, 2002). In the year 2007, 57 percent made no change (Equity and Bond Ownership of America, 2008).

[21]Specifically, 55 percent of those conducting transactions in 2007 reported rebalancing as a reason. But on average respondents gave 3 to 4 reasons for conducting transactions. We do not know what fraction exclusively conducted transactions for rebalancing purposes.

The model does a good job accounting for all of the data moments when $\psi = 1$. All non-targeted moments are close to those in the data. The model is also consistent with a variety of other stylized facts documented in the literature. The first is the fact that asset prices are mostly driven by financial shocks (e.g. Koijen and Yogo (2019) for equity and Itskhoki and Muhkin (2021) for exchange rates) and therefore disconnected from observed fundamentals like dividends. Table 3 reports the contribution of the shocks to the variance of the excess return and net capital flows, with column (ii) reporting results for the $\psi = 1$ case. We see that 91 percent of the variance of the excess return is driven by financial shocks. This is also evident from Figure 1, which shows impulse response functions for one standard deviation shocks. Financial shocks are clearly the dominant driver of the relative asset price.

The large role of financial shocks is a result of a large price impact parameter M of 1.5 in the last row of Table 2. It is somewhat lower than the price impact of 5 estimated for the equity market by Gabaix and Koijen (2020) through Granual Instrumental Variables (GIV). But that is as expected as the assets in this paper are broader claims on capital that are less risky. Lower risk leads to a stronger portfolio response to expected returns, which reduces the price impact. As we will see, a price impact of 1.5 is a substantial order of magnitude larger than in the frictionless case.

The literature has also documented extensive evidence in a broad set of financial markets of excess return momentum and reversal. For example, Moskowitz et al. (2012) document momentum and reversal in commodity, equity, currency and bond markets. They show that excess returns are positively correlated with their own lag up to about 12 months (momentum), while they are negatively autocorrelated for longer lags (reversal).[22] The model with $\psi = 1$ is consistent with both momentum and reversal. It generates a positive autocorrelation of the excess return of 0.15 (Table 2), close to that in the data. In response to financial shocks the relative price continues to go up for two additional quarters after the initial shock (Figure 2, panel A), which generates a positive autocorrelation of the excess return. After that it starts to fall (negative excess returns), consistent with reversal.[23]

The model is also in agreement with a significant literature on post-earnings announcement drift (see Fink (2021) for a recent review), which says that stock prices continue to rise for months or quarters subsequent to a positive earnings announcement. Panel C of Figure 1

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[22]See also Jegadeesh and Titman (1993), Lim et al. (2018), Chan et al. (1997) and Cutler et al. (1991) for evidence of momentum and De Bondt and Thaler (1985), Fama and French (1998) and Poterba and Summers (1988) for evidence of reversal.

[23]To establish evidence of momentum and reversal, the literature has used evidence on many firms, commodities and currencies. In this paper we only have a time series for one relative price (US relative to the rest of the G7), which is not sufficient. When we use the relative price of each of the six non-US G7 countries relative to the US, we find marginal evidence of momentum. The pooled regression $q_{t+1}^{D,i} - q_t^{D,i} = a_0 + a_1 \left(q_t^{D,i} - q_{t-1}^{D,i} \right)$, where $q^{D,i}$ is the log price of country i relative to the US, delivers a coefficient $a_1 = 0.0663$ with a t-value of 1.67.

shows that a positive productivity or capital share shock, which both raise dividends, leads to a continued rise in the relative price for an additional quarter after the shock.

We can conclude that the model is consistent with a broad set of evidence related to asset prices. Taking the case of $\psi = 1$ seriously, we can use the variance decomposition in Table 3 and impulse response functions in Figure 1 to draw conclusions regarding the impact of the various shocks on the relative price and net capital flows. Productivity and capital share shocks are very similar as they both affect dividends. Together they are simply referred to as dividend shocks in Table 3. Investment shocks are also similar to dividend shocks in terms of the impact on the relative price, which operates largely through the effect on relative dividends. A rise in m_t^D lowers relative Home investment, which lowers the relative Home capital stock, which raises the relative Home dividend.[24]

In terms of the relative price, we have already noted that financial shocks dominate. The impact of saving shocks is nil, while investment and dividend shocks together account for about 10 percent of the variance of the excess return. Saving shocks raise the left hand side of the equilibrium condition $S - I = NF$, while financial shocks lower the right hand side. The reason that saving shocks have a much smaller effect on the relative price than financial shocks is that they are very small as a fraction of the entire financial market. The other shocks affect dividends, which affect the expected excess return and therefore NF. Even with the portfolio friction, this perturbs the equilibrium condition $S - I = NF$ more than saving shocks, though much less than financial shocks.

Table 3 shows that net capital flows are dominated by financial shocks and saving shocks. They each account for about 47 percent of the variance of net capital flows. Financial shocks affect net capital flows through the relative price, which affects relative investment through the Tobin Q relationship and relative saving through its impact on relative wealth and therefore relative consumption. As discussed, the link between investment and Tobin Q is calibrated to be realistic, while the marginal propensity to consume out of wealth of 4 percent per year in the model is also within the range of estimates in the literature.

Saving shocks also have a significant effect on net capital flows. Since they have very little effect on the relative price, there is limited feedback from the relative asset price change back to saving and investment. Therefore a rise in Home saving corresponds to capital outflows of virtually the same magnitude. This is not the case for an investment shock, which affects dividends and therefore requires a larger price adjustment that mitigates the impact on equilibrium net capital flows.

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[24]The lower relative Home capital stock also raises the relative price through a supply effect. But this is weaker than its effect through the relative dividend.

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4.1.2 Larger Portfolio Friction: $\psi = 3$

We now consider a larger friction of $\psi = 3$. This implies $\eta = 0.957$. Drawing again an analogy to a Calvo type portfolio friction, it implies that about 84 percent of investors make no portfolio change during the course of a year. This is on the high side given the 60 percent of investors that make no change to their stock or mutual fund portfolios. However, we cannot dismiss it outright. As discussed in the introduction, 90 percent of investors make no change to their retirement portfolio during a given year.

With one exception, the model with $\psi = 3$ does a good job in matching the non-targeted moments in Table 2 (see column (iii)). The exception is the autocorrelation of the excess return. It is 0.35, which is more than three standard deviations above the data. As we raise ψ, portfolios adjust more gradually, which gives rise to a more gradual adjustment of asset prices in response to shocks, leading to a higher autocorrelation of the excess return. With $\psi = 3$ there is stronger momentum. Figure 2, which shows impulse responses when $\psi = 3$, shows that the excess return continues to rise for three more quarters after a positive financial shock. There is also significant post-earnings announcement drift as the relative price continues to rise for several quarters after a positive dividend shock (through either productivity or the capital share).

Both from evidence on the frequency of portfolio changes and the extent of momentum implied by $\psi = 3$, it appears that this level of the friction is a bit too high to be consistent with the data. Not surprisingly, the higher portfolio friction implies a larger price impact of $M = 2.2$, requiring smaller financial shocks to be consistent with the data (see bottom of Table 2, column (iii)).

4.1.3 Frictionless Case: $\psi = 0$

Column (i) of Table 2 reports model moments without any portfolio friction ($\psi = 0$). At first it looks like the model performs well without any portfolio friction. However, this only occurs as a result of massive financial shocks. The size of a one standard deviation financial shock (second row from bottom) is 0.21. This corresponds to an exogenous portfolio shift that leads to a change in demand for the Home asset equal to 21 percent of the entire Home financial market during just one quarter. By contrast, the financial shock is only 1.7 percent of the market when $\psi = 1$ and 1.1 percent when $\psi = 3$.

The reason that such a large financial shock is needed without the portfolio friction is that financial shocks have little price impact. Without portfolio frictions, portfolios are very sensitive to changes in expected returns. A financial shock is therefore easily absorbed through a small change in the expected excess return that involves a very small change in the relative asset price. We are then unable to account for the observed volatility of the

excess return, and the low correlation between the relative price change and relative dividend change, unless financial shocks are massive in size.

The last row of Table 2 reports a price impact of $M = 0.12$ when $\psi = 0$. This means that the relative price rises only 0.12 percent in response to a 1 percent portfolio shift towards the Home market. This is a factor 16 smaller than when $\psi = 1$ and a factor 19 smaller compared to $\psi = 3$. The price impact with frictions is much closer to what Gabaix and Koijen (2020) estimate for the equity market.

The frictionless case also does not produce any excess return momentum and reversal or post-earnings announcement drift. Figure 3 shows impulse responses when $\psi = 0$. In response to financial shocks and both types of dividend shocks, the relative price gradually drops over time after its increase at the time of the shock. Even if we made the rate of relative risk aversion very high, which would increase the price impact of financial shocks, this lack of momentum would remain. It explains why the excess return is slightly negatively autocorrelated in Table 2 when $\psi = 0$. Introducing other features that raise the price impact of financial shocks, such as segmented markets or disaster risk, are analogous to simply raising risk aversion and therefore would not generate asset price momentum or reversal.

Table 3 shows that it remains the case that close to 90 percent of the variance of the relative price is driven by financial shocks, while financial and saving shocks dominate net capital flows. However, this happens only because we adjust the size of financial shocks to an implausible level.

To summarize, the model best describes the data for an intermediate value of the portfolio friction. Without the friction, implausibly large financial shocks are needed and there is no asset price momentum, reversal or post-earnings announcement drift. When the friction is too large, there is too much momentum. The autocorrelation of the excess return becomes too large.

4.2   Impact of Change in Portfolio Friction

So far we changed five other parameters when changing the portfolio friction, targeting several moments. We now hold the other parameters constant in order to see the impact of changing the portfolio friction by itself. Specifically, we hold other parameters constant at their level for the $\psi = 1$ case, shown in Table 1 and corresponding to column (ii) of Table 2. We only adjust σ_τ in order to keep the size of a one standard deviation financial shock constant as we change ψ. Another way to put this is that we hold constant the process of the portfolio shift variable $f_t = \lambda \tau_t^D$ in (12). The purpose of this exercise is purely to understand what the friction does in the model. It is not reasonable to compare the performance of the model across these cases as we only target key moments in the $\psi = 1$ case.

For all three values of ψ, Figure 4 reports the impulse response functions of the relative

price and net capital flows to one standard deviation shocks. Chart A of Figure 4 shows that the impact of financial shocks on the relative price is enormously affected by the level of ψ. The impact is much larger with $\psi = 1$ than $\psi = 0$ and much larger when $\psi = 3$ than $\psi = 1$. This is as expected as a larger portfolio friction implies a weaker portfolio response to changes in expected returns, requiring larger relative price changes to generate equilibrium in response to a financial shocks. Panel B of Figure 4 shows that the impact of financial shocks on net capital flows is also much larger as we raise ψ. This is again because both relative saving and investment are linked to the relative price.

These results are also reflected in Tables 2 and 3, where columns (iv) and (v) report results for $\psi = 0$ and $\psi = 3$ when holding the other parameters constant at the level for $\psi = 1$. Consistent with the impulse response functions, Table 3 shows that the contribution of financial shocks to the variance of the relative price and net capital flows are both nil when we lower ψ to zero. By contrast, when we raise ψ to 3, the large price impact of financial shocks implies that they account for 99 percent of the variance of the relative price and 91 percent of the variance of net capital flows. Table 2 shows that lowering ψ to 0 reduces the standard deviation of the excess return to about one third of that in the data, while raising ψ to 3 raises the volatility of the excess return to more than twice that in the data. This is all related to the much larger impact of financial shocks as we raise the portfolio friction.

The portfolio friction also affects the response to the other shocks. First consider the relative price. Similar to financial shocks, panel C of Figure 4 shows that the price impact of saving shocks is larger when the portfolio friction increases. Conversely, panels E and G show that the price impact of the other shocks is weaker as ψ increases. We do not show productivity shocks as the impact is similar to capital share shocks, both affecting relative dividends.

Just like financial shocks, saving shocks require a larger change in the relative price to equate $S - I$ to NF when ψ rises as the portfolio share is less sensitive to expected excess returns. However, even for large ψ the price effect remains small since saving shocks are small relative to the overall financial market. The other shocks, including investment shocks, affect the relative price largely through their effect on relative dividends. The larger ψ, the smaller the portfolio response to a change in expected relative dividends (which affect the excess return), leading to a smaller initial price effect.

Next consider net capital flows. The response of net capital flows to saving shocks is affected only to a small extent by the friction. This is due to the small price impact of saving shocks, even with the friction, leading to limited feedback to saving and investment and therefore net capital flows. The response of net capital flows to dividend and investment shocks is increased under a higher portfolio friction. Investment shocks and capital share shocks both lead to net capital outflows. For investment shocks, a rise in m_t^D lowers relative

Home investment, giving rise to a positive current account (net outflows). For capital share shocks, a rise in θ_t^D raises the relative Home dividend, which raises relative Home saving, also generating net outflows. The increase in the relative price for both shocks lowers saving and raises investment, which dampens the size of net outflows. Higher portfolio frictions weaken the initial price impact, leading to larger equilibrium net outflows.

Overall we can conclude that the size of net capital flows is increased when we raise the portfolio friction. A smaller friction leads to smaller net capital flows. Only for saving shocks does the friction not matter much. This means that the relative importance of saving shocks for net capital flows increases as we lower the friction and falls as we raise the friction. We see in Table 3, column (iv), that lowering ψ to zero raises the contribution of saving shocks to the variance of net capital flows to 91 percent. By contrast, raising ψ to 3 (column (v) of Table 3), saving shocks account for only 8 percent of the variance of net capital flows and financial shocks account for 91 percent.

4.3 Robustness Analysis

We consider two types of robustness analysis. We first introduce a buy-and-hold portfolio friction, where there is a quadratic cost of deviating from the buy-and-hold portfolio instead of the lagged portfolio. After that we consider how results change for different values of the rate of risk aversion γ and persistence ρ_τ of financial shocks.

4.3.1 Buy-and-Hold Portfolio Friction

We have so far assumed that the portfolio friction takes the form

$$\psi(z_{h,t} - z_{h,t-1})^2$$

We now replace this with

$$\psi(z_{h,t} - z_{h,t}^{bh})^2$$

where $z_{h,t}^{bh}$ is the buy-and-hold portfolio. This is the portfolio at time t if investors do not buy or sell any assets. In this case there is a cost associated with any asset trade, even if it is just for the purpose of portfolio rebalancing. A higher friction will now reduce the extent of portfolio rebalancing, which further weakens the response of net capital flows NF to changes in the relative asset price.

The buy-and-hold portfolio is equal to

$$z_{h,t}^{bh} = \frac{z_{h,t-1}\frac{Q_{H,t}}{Q_{H,t-1}}}{z_{h,t-1}\frac{Q_{H,t}}{Q_{H,t-1}} + (1 - z_{h,t-1})\frac{Q_{F,t}}{Q_{F,t-1}}} \tag{40}$$

Linearizing, we have

$$z_{h,t}^{bh} = z_{h,t-1} + \bar{z}(1 - \bar{z})\Delta q_t^D \tag{41}$$

We therefore modify the Bellman equation (2) by replacing the portfolio cost $\psi(z_{h,t} - z_{h,t-1})^2$ with

$$\psi\left(z_{h,t} - z_{h,t-1} - \bar{z}(1 - \bar{z})\Delta q_t^D\right)^2 \tag{42}$$

We leave all algebraic details of this extension to the Online Appendix.

Columns (vi) and (vii) of Table 2 report the model moments when $\psi = 1$ and $\psi = 3$. Obviously there is no impact for the frictionless case of $\psi = 0$. We again change other parameters to target five moments. We can compare to columns (ii) and (iii), where there is a quadratic cost in deviation from the lagged portfolio. A couple of points stand out. First, the size of the financial shock (near the bottom of the table) is now even smaller. When $\psi = 3$, a one standard deviation financial shock is now only 0.75 percent of the Home asset market (versus 1.1 percent before). A smaller financial shock is needed as asset prices are now even more sensitive to financial shocks. This is due to weaker portfolio rebalancing. Related to that, the price impact parameter M at the very bottom of the Table is now 3.2 when $\psi = 3$, compared to 2.2 before.

The other significant difference is that the autocorrelation of the excess return is now -0.005 for both $\psi = 1$ and $\psi = 3$. This is especially remarkable for $\psi = 3$, where the autocorrelation of the excess return was too high with a cost of deviating from the lagged portfolio. This is no longer a problem with the buy-and-hold friction. The autocorrelation is within two standard errors of the data and if anything is on the low side. There is no longer asset price momentum.

When the portfolio cost relates to a deviation from the lagged portfolio, investors change their portfolio gradually. This leads to a more gradual response of the relative price to shocks, as clearly seen in the humped shaped price response to financial shocks in panel A of Figure 2 and in panel C for dividend shocks. This gives rise to a positive autocorrelation of the excess return. We find that this is no longer the case when the portfolio cost relates to a deviation from the buy-and-hold portfolio. For all shocks, when the price rises at the time of the shock, it will subsequently slowly fall. This accounts for the lower, and even slightly negative, autocorrelation of the excess return.

To understand the difference, consider a financial shock that leads to a persistent flow into the Home market. With a cost of deviating from the lagged portfolio, portfolio rebalancing is critical to generating equilibrium. As the price gradually increases, the expected excess return is initially positive. This leads to an even larger flow into the Home market. Equilibrium is established as investors sell the Home asset for portfolio rebalancing reasons. But the buy-and-hold portfolio friction significantly weakens portfolio rebalancing. Then

equilibrium needs to be established through a lower expected excess return on the Home asset that leads investors to sell the Home asset. This means that the relative price must slowly drop after the initial increase, which is exactly what happens.

In reality both types of portfolio costs are likely to be important. We could introduce an intermediate case where there is both a cost of deviating from the lagged portfolio and the buy-and-hold portfolio. Bacchetta, Tièche and van Wincoop (2021) provide evidence that both of these costs are positive when considering global portfolios of US equity mutual funds.

4.3.2   Sensitivity Analysis

We finally consider the sensitivity of results to two important parameters, γ and ρ_τ. We find that when we redo the first three columns of Table 2 for different values of these parameters, the moments do not change significantly, as long as we keep adjusting the other parameters to match the targeted moments. However, what does change significantly is the size of financial shocks needed to match these moments and the price impact parameter M (bottom two rows of Table 2). Table 4 reports these two variables for alternative values of γ and ρ_τ. For comparison, it shows the baseline results as well, where $\gamma = 10$ and $\rho_\tau = 0.99$.

We first raise γ to 100. That is clearly excessively large, but is meant to illustrate an alternative way to weaken the portfolio response to expected returns, even without portfolio frictions.[25] As a result, the size of financial shocks needed to account for the data is smaller and the price impact parameter M is much larger. But we can see from Table 4 that even with $\gamma = 100$, M remains much smaller than under the baseline with the portfolio friction.

In fact, no matter how much we raise risk aversion in the frictionless case, we never match the level of M when either $\psi = 1$ or $\psi = 3$ and $\gamma = 10$. Even if we set γ equal to infinity in the frictionless case, so that we completely shut down the portfolio response to expected returns, the price impact is still substantially larger with the friction. This is because with the friction a financial shock leads to a hump-shaped price response. Initially the relative price therefore continues to rise. This leads to positive expected excess returns on the Home asset that generate a further shift towards the Home asset, amplifying the impact of the financial shock. This does not happen under the buy-and-hold friction, but in that case M is even bigger because it weakens portfolio rebalancing as an equilibrating mechanism.

Another advantage of weakening the portfolio response to expected returns through the portfolio friction, as opposed to a very large γ, is that it can account for excess return momentum and reversal, as well as post-earnings announcement drift. In the frictionless case we cannot generate this, no matter how large γ.

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[25]As discussed, this could alternatively be done by increasing perceived risk (e.g. infrequent disaster risk) or introducing market segmentation.

The last two rows of Table 4 consider a lower and higher value of the persistence of the financial shock. The persistence is $\rho_\tau = 0.99$ in the baseline case. We first lower it significantly to 0.95 and then raise it to 0.995. A lower persistence implies that larger financial shocks are needed to account for the targeted moments, especially excess return volatility. In the frictionless case, a one standard deviation financial shock is now equal to 49 percent of the Home asset market and the price impact parameter M is only 0.05. Raising ρ_τ to 0.995 does the opposite, although the changes there are relatively modest. It remains the case that in the frictionless case excessively large financial shocks are needed to account for the data moments and the price impact parameter M is very small.

5   Conclusion

Over the past decade, portfolio choice has become an important element of many DSGE open economy models. However, standard frictionless portfolio choice models have implications that are at odds with both micro and macro evidence. In this paper we have introduced a portfolio adjustment friction into a two-country DSGE model. While there is a literature that has introduced similar frictions, this has usually been in the context of partial equilibrium models. Here we have introduced the friction into an otherwise quite standard two-country DSGE model by assuming that the assets are broad claims on capital stocks. This allows us to investigate not just the asset pricing implications, but also overall net capital flows.

Portfolio adjustment frictions allow us to connect better to the data in a variety of ways. First, it connects to micro evidence of infrequent portfolio adjustment by households. Second, it implies a much larger price impact of financial shocks, addressing a criticism by Gabaix and Koijen (2020) of frictionless models. Related to that, it can account for evidence that financial shocks are the dominant driver of asset prices and asset prices are disconnected from observed fundamentals. Third, it can account for a variety of moments involving national saving, investment and net capital flows. Finally, it can account for evidence of excess return momentum and reversal in a broad set of financial markets, and related post-earnings announcement drift.

The portfolio friction plays an important role for both asset prices and capital flows. We find that a higher portfolio friction significantly increases the impact of financial shocks on asset prices, while reducing the price impact of shocks that affect dividends (productivity shocks, capital share shocks and investment shocks). For net capital flows the portfolio friction increases the impact of both financial shocks and shocks that affect dividends. The effect of saving shocks on net capital flows is little impacted by the friction. In a plausible calibration we find that financial and saving shocks both account for close to half of the variance of net capital flows.

An important direction for future research is further measurement of the magnitude of portfolio frictions. While Bacchetta, Tièche and van Wincoop (2021) do so for US mutual funds that invest in foreign equity, it will be important to consider the portfolio behavior of individual households. A substantial literature has documented portfolio inertia by households, but has not estimated portfolio expressions implied by such frictions. The behavior of individual households is important even when they invest in actively managed mutual funds as it is up to households to make reallocation decisions between these funds.

Appendix

A Derivation Portfolio Expressions

Although all investors in each country will make the same portfolio and consumption decisions, it is useful to introduce superscripts i for investors from a particular country, assuming that there is a continuum of investors in each country on the interval $[0,1]$. The portfolio share of investor i from country h allocated to the Home country is then $z_{h,t}^i$, consumption is $C_{h,t}^i$, and the portfolio return is $R_{t+1}^{p,h,i}$. The Bellman equation is

$$\ln(V_{h,t}^i) = \max_{C_{h,t}^i, z_{h,t}^i} \left\{ (1 - \beta_{h,t}) \ln(C_{h,t}^i) + \beta_{h,t} \left[\ln \left(\left[E_t \left(V_{h,t+1}^i \right)^{1-\gamma} \right]^{\frac{1}{1-\gamma}} \right) - 0.5\psi(z_{h,t}^i - z_{h,t-1}^i)^2 \right] \right\} \tag{A.1}$$

Wealth $W_{h,t}^i$ evolves according to

$$W_{h,t+1}^i = R_{t+1}^{p,h,i} \left(W_{h,t}^i - C_{h,t}^i \right) \tag{A.2}$$

where the portfolio return is

$$R_{t+1}^{p,H,i} = z_{H,t}^i R_{H,t+1} + (1 - z_{H,t}^i)e^{-\tau_{H,t}} R_{F,t+1} + T_{H,t+1} \tag{A.3}$$

$$R_{t+1}^{p,F,i} = z_{F,t}^i e^{-\tau_{F,t}} R_{H,t+1} + (1 - z_{F,t}^i) R_{F,t+1} + T_{F,t+1} \tag{A.4}$$

The costs $\tau_{h,t}$ are reimbursed lump sum through $T_{h,t}$, which depends on the average portfolio share $z_{h,t} = \int_0^1 z_{h,t}^i di$ that the agent cannot control. In equilibrium all agents will then earn the portfolio returns

$$R_{t+1}^{p,H} = z_{H,t} R_{H,t+1} + (1 - z_{H,t}) R_{F,t+1} \tag{A.5}$$

$$R_{t+1}^{p,F} = z_{F,t} R_{H,t+1} + (1 - z_{F,t}) R_{F,t+1} \tag{A.6}$$

Conjecture that the value function takes the form

$$V_{h,t}^i = W_{h,t}^i e^{f_h(\mathbf{S}_t, z_{h,t-1}^i)} \tag{A.7}$$

The function f_h captures expected future portfolio returns and risk. It depends both on a vector $\mathbf{S}_t$ of aggregate state variables that agent i cannot control and on $z_{h,t-1}^i$. We then have

$$V_{h,t+1}^i = (W_{h,t}^i - C_{h,t}^i) R_{t+1}^{p,h,i} e^{f_h(\mathbf{S}_{t+1}, z_{h,t}^i)} \tag{A.8}$$

Note that $z_{h,t}^i$, a control variable of agent i at time t, affects $V_{h,t+1}^i$ both through the portfolio

return and through $f_h(\mathbf{S}_{t+1}, z_{h,t}^i)$. Denote

$$\lambda_{h,t}^i = \frac{\partial f_{h,t}^i}{\partial z_{h,t-1}^i} \tag{A.9}$$

where $f_{h,t}^i = f_h(\mathbf{S}_t, z_{h,t-1}^i)$. We then also have

$$\lambda_{h,t+1}^i = \frac{\partial f_{h,t+1}^i}{\partial z_{h,t}^i} \tag{A.10}$$

where $f_{h,t+1}^i = f_h(\mathbf{S}_{t+1}, z_{h,t}^i)$.

The Bellman equation can be written as

$$\ln(V_{h,t}^i) = \max_{C_{h,t}^i, z_{h,t}^i} \left\{ (1 - \beta_{h,t}) \ln(C_{h,t}^i) + \beta_{h,t} ln(W_{h,t}^i - C_{h,t}^i) - 0.5\beta_{h,t}\psi(z_{h,t}^i - z_{h,t-1}^i)^2 + \right.$$
$$\left. \beta_{h,t} \frac{1}{1-\gamma} ln \left(E_t \left(R_{t+1}^{p,h,i} \right)^{1-\gamma} e^{(1-\gamma)f_h(\mathbf{S}_{t+1}, z_{h,t}^i)} \right) \right\} \tag{A.11}$$

The first-order condition for consumption is

$$C_{h,t}^i = (1 - \beta_{h,t})W_{h,t}^i. \tag{A.12}$$

The portfolio problem is

$$\max_{z_{h,t}^i} \left\{ \frac{1}{1-\gamma} ln \left(E_t \left(R_{t+1}^{p,h,i} \right)^{1-\gamma} e^{(1-\gamma)f_h(\mathbf{S}_{t+1}, z_{h,t}^i)} \right) - 0.5\psi(z_{h,t}^i - z_{h,t-1}^i)^2 \right\} \tag{A.13}$$

The portfolio Euler equation for Home and Foreign agents is

$$E_t e^{-\gamma r_{t+1}^{p,H,i} + r_{H,t+1} + (1-\gamma)f_{H,t+1}^i} - E_t e^{-\gamma r_{t+1}^{p,H} + r_{F,t+1} - \tau_{H,t} + (1-\gamma)f_{H,t+1}^i} + \tag{A.14}$$
$$E_t e^{(1-\gamma)r_{t+1}^{p,H,i} + (1-\gamma)f_{H,t+1}^i} \lambda_{H,t+1}^i = \psi(z_{H,t}^i - z_{H,t-1}^i) E_t e^{(1-\gamma)r_{t+1}^{p,H,i} + (1-\gamma)f_{H,t+1}^i}$$
$$E_t e^{-\gamma r_{t+1}^{p,F,i} + r_{H,t+1} - \tau_{F,t} + (1-\gamma)f_{F,t+1}^i} - E_t e^{-\gamma r_{t+1}^{p,F,i} + r_{F,t+1} + (1-\gamma)f_{F,t+1}^i} + \tag{A.15}$$
$$E_t e^{(1-\gamma)r_{t+1}^{p,F,i} + (1-\gamma)f_{F,t+1}^i} \lambda_{F,t+1}^i = \psi(z_{F,t}^i - z_{F,t-1}^i) E_t e^{(1-\gamma)r_{t+1}^{p,F,i} + (1-\gamma)f_{F,t+1}^i}$$

Here the lower case r refers to log asset returns and portfolio returns.

The Bellman equations are

$$f_{h,t}^i = \beta_{h,t} ln(\beta_{h,t}) + (1 - \beta_{h,t}) ln(1 - \beta_{h,t}) + \tag{A.16}$$
$$\frac{\beta_{h,t}}{1-\gamma} ln \left(E_t e^{(1-\gamma)r_{t+1}^{p,h,i} + (1-\gamma)f_{h,t+1}^i} \right) - 0.5\beta_{h,t}\psi(z_{h,t}^i - z_{h,t-1}^i)^2$$

It follows that

$$\lambda_{h,t}^i = \beta_{h,t}\psi(z_{h,t}^i - z_{h,t-1}^i) \tag{A.17}$$

We can now remove the i superscripts. Define

$$f_{h,t} = f_h(\mathbf{S}_t, z_{h,t-1})$$
$$\lambda_{h,t} = \beta_{h,t}\psi(z_{h,t} - z_{h,t-1})$$

Note that $f_{h,t+1} = f_h(\mathbf{S}_{t+1}, z_{h,t})$. $f_{h,t+1}$ now depends only on the aggregate state at $t + 1$.

The first-order portfolio Euler conditions for Home agents are

$$E_t e^{-\gamma r_{t+1}^{p,H} + r_{H,t+1} + (1-\gamma)f_{H,t+1}} - E_t e^{-\gamma r_{t+1}^{p,H} + r_{F,t+1} - \tau_{H,t} + (1-\gamma)f_{H,t+1}} +$$
$$E_t e^{(1-\gamma)r_{t+1}^{p,H} + (1-\gamma)f_{H,t+1}}\psi\beta_{H,t+1}(z_{H,t+1} - z_{H,t}) =$$
$$\psi(z_{H,t} - z_{H,t-1})E_t e^{(1-\gamma)r_{t+1}^{p,H} + (1-\gamma)f_{H,t+1}} \tag{A.18}$$

Analogously, the first-order portfolio Euler condition for Foreign agents is

$$E_t e^{-\gamma r_{t+1}^{p,F} + r_{H,t+1} - \tau_{F,t} + (1-\gamma)f_{F,t+1}} - E_t e^{-\gamma r_{t+1}^{p,F} + r_{F,t+1} + (1-\gamma)f_{F,t+1}} +$$
$$E_t e^{(1-\gamma)r_{t+1}^{p,F} + (1-\gamma)f_{F,t+1}}\psi\beta_{F,t+1}(z_{F,t+1} - z_{F,t}) =$$
$$\psi(z_{F,t} - z_{F,t-1})E_t e^{(1-\gamma)r_{t+1}^{p,F} + (1-\gamma)f_{F,t+1}} \tag{A.19}$$

Consider the portfolio Euler for Home investors. Denote $\hat{x}_{t+1} = x_{t+1} - E_t x_{t+1}$. The Home portfolio Euler can then be written as

$$E_t e^{(1-\gamma)\hat{r}_{t+1}^{p,H} + r_{H,t+1} - r_{t+1}^{p,H} + (1-\gamma)\hat{f}_{H,t+1}} - E_t e^{(1-\gamma)\hat{r}_{t+1}^{p,H} + r_{F,t+1} - r_{t+1}^{p,H} - \tau_{H,t} + (1-\gamma)\hat{f}_{H,t+1}} +$$
$$E_t e^{(1-\gamma)\hat{r}_{t+1}^{p,H} + (1-\gamma)\hat{f}_{H,t+1}}\psi\beta_{H,t+1}(z_{H,t+1} - z_{H,t}) =$$
$$\psi(z_{H,t} - z_{H,t-1})E_t e^{(1-\gamma)\hat{r}_{t+1}^{p,H} + (1-\gamma)\hat{f}_{H,t+1}} \tag{A.20}$$

For the first, second and fourth terms we will approximate by taking the expectation of the exponential terms, assuming normality, and then linearizing around expectation and variance terms in the exponential being zero.

We cannot follow this procedure for the third term as the exponential term is multiplied by a stochastic variable. We instead take a second-order Taylor expansion and then take the expectation. Note that this will deliver the same result if it were just an exponential term. Treating portfolio shares as a parameter around which we do not linearize, the second-order Taylor expansion is

$$\psi\beta_{H,t+1}(z_{H,t+1} - z_{H,t}) + \psi\beta\left((1-\gamma)\hat{r}_{t+1}^{p,H} + (1-\gamma)\hat{f}_{H,t+1}\right)(z_{H,t+1} - z_{H,t}) \tag{A.21}$$

The expectation of the third term in the portfolio Euler then becomes

$$\psi E_t \beta_{H,t+1}(E_t z_{H,t+1} - z_{H,t}) + \psi cov(\beta_{H,t+1}, z_{H,t+1})$$
$$+\psi\beta(1-\gamma)cov(r_{t+1}^{p,H}, z_{H,t+1}) + \psi\beta(1-\gamma)cov(f_{H,t+1}, z_{H,t+1}) \qquad (A.22)$$

Linearizing the first term, this becomes

$$\psi\beta(E_t z_{H,t+1} - z_{H,t}) + \omega \qquad (A.23)$$

where

$$\omega = \psi cov(\beta_{H,t+1}, z_{H,t+1}) + \psi\beta(1-\gamma)cov(r_{t+1}^{p,H}, z_{H,t+1}) + \psi\beta(1-\gamma)cov(f_{H,t+1}, z_{H,t+1}) \quad (A.24)$$

We will treat ω as a constant hedge term.

For the first two terms of the Home portfolio Euler (A.20), we compute the expectation of the exponential and then linearize with respect to a zero variance and expectation (and a zero tax). Combining the first two terms gives

$$E_t er_{t+1} + \tau_{H,t} + 0.5var(r_{H,t+1}) - 0.5var(r_{F,t+1}) - \gamma cov(er_{t+1}, r_{t+1}^{p,H}) + (1-\gamma)cov(er_{t+1}, f_{H,t+1})$$
$$(A.25)$$

Using the linear approximation $r_{t+1}^{p,H} = z_{H,t} er_{t+1} + r_{F,t+1}$, we can write this as

$$E_t er_{t+1} + \tau_{H,t} - \gamma\sigma^2 z_{H,t} - \gamma cov(er_{t+1}, r_{F,t+1}) + 0.5var(r_{H,t+1}) - 0.5var(r_{F,t+1}) + (1-\gamma)cov(er_{t+1}, f_{H,t+1})$$
$$(A.26)$$

where $\sigma^2 = var(er_{t+1})$.

For the last term of the Home portfolio Euler (A.20), first compute the expectation of the exponential, then linearize, including with respect to portfolio shares. This gives

$$\psi(z_{H,t} - z_{H,t-1}) \qquad (A.27)$$

To summarize, we have

$$\beta\psi(E_t z_{H,t+1} - z_{H,t}) + E_t er_{t+1} + \tau_{H,t} - \psi(z_{H,t} - z_{H,t-1}) - \gamma\sigma^2 z_{H,t} + \nu_H = 0 \qquad (A.28)$$

where

$$\nu_H = \omega + 0.5var(r_{H,t+1}) - 0.5var(r_{F,t+1}) - \gamma cov(er_{t+1}, r_{F,t+1}) + (1-\gamma)cov(er_{t+1}, f_{H,t+1})$$

This is a hedge term that we treat as a constant.

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Collecting terms, we have

$$\beta\psi E_t z_{H,t+1} - \left(\gamma\sigma^2 + \psi(1+\beta)\right) z_{H,t} + \psi z_{H,t-1} + E_t er_{t+1} + \tau_{H,t} + \nu_H = 0 \qquad \text{(A.29)}$$

Following the same approximation method for the Foreign portfolio Euler equation, we have

$$\beta\psi E_t z_{F,t+1} - \left(\gamma\sigma^2 + \psi(1+\beta)\right) z_{F,t} + \psi z_{F,t-1} + E_t er_{t+1} - \tau_{F,t} + \nu_F = 0 \qquad \text{(A.30)}$$

Taking the average of these equations, it follows that

$$\beta\psi E_t z_{t+1}^A - \left(\gamma\sigma^2 + \psi(1+\beta)\right) z_t^A + \psi z_{t-1}^A + E_t er_{t+1} + 0.5\tau_t^D + \nu^A = 0 \qquad \text{(A.31)}$$

As a result of symmetry, in the the risky steady state $z^A = 0.5$ and the expected excess return is zero. It then follows that $\nu^A = 0.5\gamma\sigma^2$.

B Linear System of Equations

We first solve the deterministic steady state. The steady state gross return is equal to $R = 1/\beta = 1 + \theta A K^{\theta-1} - \delta$. We set A such that this implies a steady state capital stock of 1. Therefore $A = (1 - \beta + \delta\beta)/(\beta\theta)$. We also have $Q = 1$, $I = \delta$, $W = 1/\beta$ and $D = (1-\beta)/\beta$.

Asset returns (22) are then log-linearized as

$$r_{h,t+1} = (1-\beta)d_{h,t+1} + \beta q_{h,t+1} - q_{h,t} \qquad \text{(B.32)}$$

while dividends (23) are log-linearized as

$$d_{h,t+1} = \frac{1-\beta+\delta\beta}{1-\beta}\left(a_{h,t+1} + \frac{1}{\theta}\theta_{h,t+1} + (\theta-1)k_{h,t+1}\right) \qquad \text{(B.33)}$$

The excess return then becomes

$$er_{t+1} = (1-\beta+\delta\beta)\left(a_{t+1}^D + \frac{1}{\theta}\theta_{t+1}^D + (\theta-1)k_{t+1}^D\right) + \beta q_{t+1}^D - q_t^D \qquad \text{(B.34)}$$

Combining (16) and (21), and log-linearizing, we have $k_{h,t+1} = k_{h,t} + (1/\zeta)(q_{h,t} - m_{h,t})$. In terms of differences and averages, this becomes

$$k_{t+1}^A = k_t^A + \frac{1}{\zeta}\left(q_t^A - m_t^A\right) \qquad \text{(B.35)}$$

$$k_{t+1}^D = k_t^D + \frac{1}{\zeta}\left(q_t^D - m_t^D\right) \qquad \text{(B.36)}$$

(3) and (8) imply that $w_{h,t+1} = r_{t+1}^{p,h} + ln(\beta_{h,t}) + w_{h,t}$. Linearizing the log portfolio return for both Home and Foreign countries, using (6)-(7), gives

$$w_{H,t+1} = w_{H,t} + \frac{1}{\beta}\beta_{H,t} + \bar{z}r_{H,t+1} + (1 - \bar{z})r_{F,t+1} \tag{B.37}$$

$$w_{F,t+1} = w_{F,t} + \frac{1}{\beta}\beta_{F,t} + (1 - \bar{z})r_{H,t+1} + \bar{z}r_{F,t+1} \tag{B.38}$$

Using (B.32)-(B.33), we then have

$$w_{t+1}^A = w_t^A + \frac{1}{\beta}\beta_t^A + \beta q_{t+1}^A - q_t^A + (1 - \beta + \delta\beta)\left(a_{t+1}^A + \frac{1}{\theta}\theta_{t+1}^A + (\theta - 1)k_{t+1}^A\right) \tag{B.39}$$

$$w_{t+1}^D = w_t^D + \frac{1}{\beta}\beta_t^D + (2\bar{z} - 1)\beta q_{t+1}^D - (2\bar{z} - 1)q_t^D$$

$$+ (2\bar{z} - 1)(1 - \beta + \delta\beta)\left(a_{t+1}^D + \frac{1}{\theta}\theta_{t+1}^D + (\theta - 1)k_{t+1}^D\right) \tag{B.40}$$

Linearizing the market clearing conditions (24)-(25) gives

$$\frac{1}{\beta}\left(\bar{z}\beta_{H,t} + (1 - \bar{z})\beta_{F,t}\right) + \bar{z}w_{H,t} + (1 - \bar{z})w_{F,t} + 2z_t^A = q_{H,t} + k_{H,t+1} \tag{B.41}$$

$$\frac{1}{\beta}\left((1 - \bar{z})\beta_{H,t} + \bar{z}\beta_{F,t}\right) + (1 - \bar{z})w_{H,t} + \bar{z}w_{F,t} - 2z_t^A = q_{F,t} + k_{F,t+1} \tag{B.42}$$

Taking the average and difference, this becomes

$$\frac{1}{\beta}\beta_t^A + w_t^A = q_t^A + k_{t+1}^A \tag{B.43}$$

$$\frac{2\bar{z} - 1}{\beta}\beta_t^D + (2\bar{z} - 1)w_t^D + 4z_t^A = q_t^D + k_{t+1}^D \tag{B.44}$$

The last linearized equation is the portfolio equation (11). After substituting the excess return (B.34), this becomes

$$\beta\psi E_t z_{t+1}^A - \left(\gamma\sigma^2 + \psi(1 + \beta)\right)z_t^A + \psi z_{t-1}^A + \tag{B.45}$$

$$(1 - \beta + \delta\beta)E_t\left(a_{t+1}^D + \frac{1}{\theta}\theta_{t+1}^D + (\theta - 1)k_{t+1}^D\right) + \beta E_t q_{t+1}^D - q_t^D + 0.5\tau_t^D = 0$$

The model is now solved by splitting the system into averages and differences. Regarding the differences, there are 9 equations: relative capital accumulation (B.36), relative wealth accumulation (B.40), relative market clearing (B.44), the portfolio expression (B.45) and five exogenous processes associated with the shocks: relative productivity shock (27), relative capital share shock (29), relative saving shock (32), relative investment shock (34) and

financial shock (35). In the Online Appendix we show that this can be reduced to a system in 8 equations, after substituting the relative market clearing conditions into the portfolio expression (B.45). Some further substitutions then lead to a system of the form $A_1 E_t x_{t+1} = A_2 x_t$, where $x_t = \left(\mathbf{S}_t, q_t^D\right)'$, where $\mathbf{S}_t$ is the vector (36) of state variables. This can be used to solve for q_t^D as a linear function of $\mathbf{S}_t$.

In terms of averages, the model can easily be solved by hand. Take the average wealth accumulation equation (B.39) one period earlier and substitute the average market clearing condition (B.43) and average capital accumulation equation (B.35). This gives

$$q_t^A = \frac{1}{1-\beta+\frac{1}{\zeta}} \left(\frac{1}{\zeta} m_t^A + \frac{1}{\beta}\beta_t^A + (1-\beta+\delta\beta)a_t^A + \frac{1}{\theta}(1-\beta+\delta\beta)\theta_t^A + (1-\beta+\delta\beta)(\theta-1)k_t^A \right)$$

(B.46)

C   Saving, Investment and Net Capital Flows

Net saving is equal to labor plus dividend income, minus consumption. Saving in country h is then

$$S_{h,t}^{net} = -(1-\beta_{h,t})W_{h,t} + \tag{C.47}$$
$$\beta_{h,t-1}W_{h,t-1} \left(\frac{z_{h,t-1}}{Q_{H,t-1}} \left(\theta_{H,t}A_{H,t}K_{H,t}^{\theta_{H,t}-1} - \delta \right) + \frac{(1-z_{h,t-1})}{Q_{F,t-1}} \left(\theta_{F,t}A_{F,t}K_{F,t}^{\theta_{F,t}-1} - \delta \right) \right)$$

Linearizing for both countries, we have

$$
\begin{aligned}
S_{H,t}^{net} &= \frac{\beta_{H,t}}{\beta} + \frac{1-\beta}{\beta^2}\beta_{H,t-1} - \frac{1-\beta}{\beta}\Delta w_{H,t} - \frac{1-\beta}{\beta}\left(\bar{z}q_{H,t-1} + (1-\bar{z})q_{F,t-1} \right) \\
&\quad + \frac{1-\beta}{\beta}\left(\bar{z}d_{H,t} + (1-\bar{z})d_{F,t} \right)
\end{aligned}
\tag{C.48}
$$

$$
\begin{aligned}
S_{F,t}^{net} &= \frac{\beta_{F,t}}{\beta} + \frac{1-\beta}{\beta^2}\beta_{F,t-1} - \frac{1-\beta}{\beta}\Delta w_{F,t} - \frac{1-\beta}{\beta}\left((1-\bar{z})q_{H,t-1} + \bar{z}q_{F,t-1} \right) \\
&\quad + \frac{1-\beta}{\beta}\left((1-\bar{z})d_{H,t} + \bar{z}d_{F,t} \right)
\end{aligned}
\tag{C.49}
$$

This uses the expression (30) for log dividends. It follows that

$$S_t^{D,net} = \frac{\beta_t^D}{\beta} + \frac{1-\beta}{\beta^2}\beta_{t-1}^D - \frac{1-\beta}{\beta}\Delta w_t^D - \frac{1-\beta}{\beta}(2\bar{z}-1)q_{t-1}^D + \frac{1-\beta}{\beta}(2\bar{z}-1)d_t^D \quad \text{(C.50)}$$

Now use that

$$\Delta w_t^D = \frac{1}{\beta}\beta_{t-1}^D + (2\bar{z}-1)\beta q_t^D + (2\bar{z}-1)(1-\beta)d_t^D - (2\bar{z}-1)q_{t-1}^D \quad \text{(C.51)}$$

This gives

$$S_t^{D,net} = \frac{\beta_t^D}{\beta} + (1-\beta)(2\bar{z}-1)\left(d_t^D - q_t^D\right) \tag{C.52}$$

Net investment is

$$I_{h,t}^{net} = \frac{1}{\zeta}\left(Q_{H,t} - e^{m_{h,t}}\right) \tag{C.53}$$

Linearizing and taking the difference across countries, we have

$$I_t^{D,net} = \frac{1}{\zeta}\left(q_t^D - m_t^D\right) \tag{C.54}$$

Therefore

$$CA_t = 0.5S_t^{D,net} - 0.5I_t^{D,net} = \frac{\beta_t^D}{\beta} + (1-\beta)(2\bar{z}-1)\left(d_t^D - q_t^D\right) - 0.5\frac{1}{\zeta}\left(q_t^D - m_t^D\right) \tag{C.55}$$

Next consider the current account from a capital flows perspective. Outflows and inflows of the Home country are

$$OF_t = (1-z_{H,t})\beta_{H,t}W_{H,t} - \frac{Q_{F,t}}{Q_{F,t-1}}(1-z_{H,t-1})\beta_{H,t-1}W_{H,t-1} \tag{C.56}$$

$$IF_t = z_{F,t}\beta_{F,t}W_{F,t} - \frac{Q_{H,t}}{Q_{H,t-1}}z_{F,t-1}\beta_{F,t-1}W_{F,t-1} \tag{C.57}$$

Linearizing, we have

$$OF_t = -\Delta z_{H,t} + (1-\bar{z})\frac{\Delta\beta_{H,t}}{\beta} + (1-\bar{z})\Delta w_{H,t} - (1-\bar{z})\Delta q_{F,t} \tag{C.58}$$

$$IF_t = \Delta z_{F,t} + (1-\bar{z})\frac{\Delta\beta_{F,t}}{\beta} + (1-\bar{z})\Delta w_{F,t} - (1-\bar{z})\Delta q_{H,t} \tag{C.59}$$

Taking the difference and using (C.51) and (C.52), we can write net capital flows as

$$NF_t = OF_t - IF_t = -2\Delta z_t^A + 2\bar{z}(1-\bar{z})\Delta q_t^D + (1-\bar{z})S_t^{D,net} \tag{C.60}$$

Using the relative market clearing condition, and a good deal of algebra, it can be checked that indeed

$$CA_t = NF_t \tag{C.61}$$

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Table 1 Calibrated Parameters ($\psi = 1$)

Parameter	Description	Parameter	Description
$\sigma = 0.0263$	standard deviation excess return	$\rho_\tau = 0.99$	persistence financial shock
$\psi = 1$	portfolio friction	$\sigma_{A,\theta} = 0.00228$	s.d. average capital share shock
$\gamma = 10$	risk-aversion	$\sigma_{D,\theta} = 0.00555$	s.d. relative capital share shock
$\zeta = 118$	adjustment cost investment	$\sigma_{A,a} = 0.00453$	s.d. average productivity shock
$\beta = 0.99$	time discount rate	$\sigma_{D,a} = 0.00694$	s.d. relative productivity shock
$\delta = 0.01125$	rate of depreciation	$\sigma_{A,\beta} = 0.000475$	s.d. average saving shock
$\theta = 0.35$	capital share	$\sigma_{D,\beta} = 0.000342$	s.d. relative saving shock
$\rho_\theta = 0.967$	persistence capital share	$\sigma_{A,m} = 0.0343$	s.d. average investment shock
$\rho_a = 0.967$	persistence productivity shock	$\sigma_{D,m} = 0.0247$	s.d. relative investment shock
$\rho_\beta = 0.99$	persistence saving shock	$\sigma_\tau = 0.00169$	s.d. financial shock
$\rho_m = 0.99$	persistence investment shock		

Table 2 Data and Model Moments

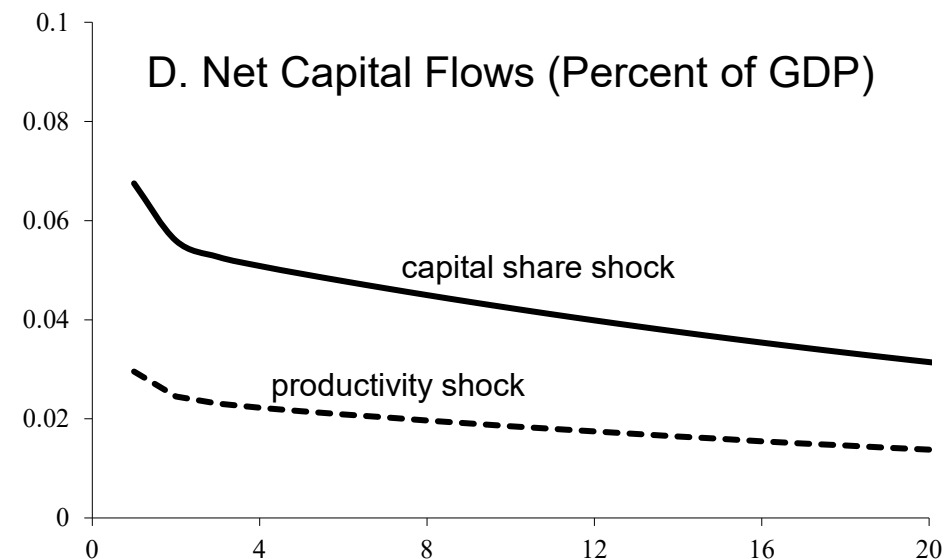|	DATA	MODEL						
		(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)
		$\psi=0$	$\psi=1$	$\psi=3$	$\psi=0$	$\psi=3$	$\psi=1$	$\psi=3$
					other parameters as column (ii)		buy-and-hold	
STANDARD DEVIATIONS								
excess return	0.0263	*0.0263*	*0.0263*	*0.0263*	0.0097	0.0638	*0.0263*	*0.0263*
		0.0015	0.0015	0.0017	0.0006	0.0042	0.0015	0.0015
$\frac{S}{Y}$	0.0222	*0.0221*	*0.0221*	*0.0222*	0.0217	0.0260	*0.0221*	*0.0221*
		0.0074	0.0075	0.0075	0.0072	0.0091	0.0074	0.0074
$\frac{I}{Y}$	0.0203	*0.0203*	*0.0203*	*0.0203*	0.0187	0.0309	*0.0203*	*0.0203*
		0.0066	0.0066	0.0067	0.0062	0.0103	0.0066	0.0066
$\frac{CA}{Y}$	0.0156	0.0167	0.0172	0.0181	0.0123	0.0399	0.0167	0.0167
		0.0056	0.0059	0.0062	0.0043	0.0139	0.0056	0.0056
Δy^D	0.0070	0.0070	0.0070	0.0070	0.0070	0.0071	0.0070	0.0070
		0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004
AUTOCORRELATIONS								
excess return	0.1030	-0.0054	0.1557	0.3565	-0.0057	0.3548	-0.0054	-0.0053
		0.0810	0.0812	0.0781	0.0787	0.0790	0.0810	0.0810
$\frac{S}{Y}$	0.9620	0.9459	0.9465	0.9475	0.9459	0.9529	0.9459	0.9459
		0.0288	0.0285	0.0278	0.0287	0.0247	0.0288	0.0288
$\frac{I}{Y}$	0.9650	0.9452	0.9472	0.9494	0.9455	0.9592	0.9452	0.9452
		0.0291	0.0280	0.0270	0.0289	0.0223	0.0291	0.0291
$\frac{CA}{Y}$	0.9730	0.9464	0.9513	0.9575	0.9468	0.9652	0.9464	0.9464
		0.0293	0.0265	0.0230	0.0302	0.0187	0.0293	0.0294
CONTEMPORANEOUS CORRELATIONS								
$corr(S/Y, I/Y)$	0.7748	0.6608	0.6411	0.6066	0.7993	0.0290	0.6610	0.6615
		0.2610	0.2742	0.2951	0.1750	0.4253	0.2609	0.2608
$corr(CA/Y, \Delta y_H)$	-0.0130	-0.0287	-0.0268	-0.0267	0.0006	-0.0824	-0.0182	-0.0182
		0.0700	0.0700	0.0701	0.0742	0.0804	0.0756	0.0756
$corr(\Delta q_H, \Delta q_F)$	0.7604	0.6499	0.7070	0.7650	0.9551	-0.0019	0.6496	0.6489
		0.0468	0.0413	0.0368	0.0075	0.0873	0.0469	0.0469
$corr(\Delta q^D, \Delta d^D)$	0.2666	0.2704	0.2287	0.1743	0.7498	0.0718	0.2703	0.2701
		0.0963	0.0984	0.1006	0.0453	0.0776	0.0963	0.0964
OTHER								
R^2 Tobin Q regression	0.2500	*0.2500*	*0.2500*	*0.2500*	0.1741	0.5829	*0.2500*	*0.2500*
		0.0966	0.0972	0.0978	0.0878	0.0873	0.0966	0.0966
size financial shock		0.2080	0.0166	0.0109	*0.0166*	*0.0166*	0.0142	0.0075
Gabaix Koijen M		0.1173	1.4783	2.1786	0.0174	3.5451	1.7181	3.2446

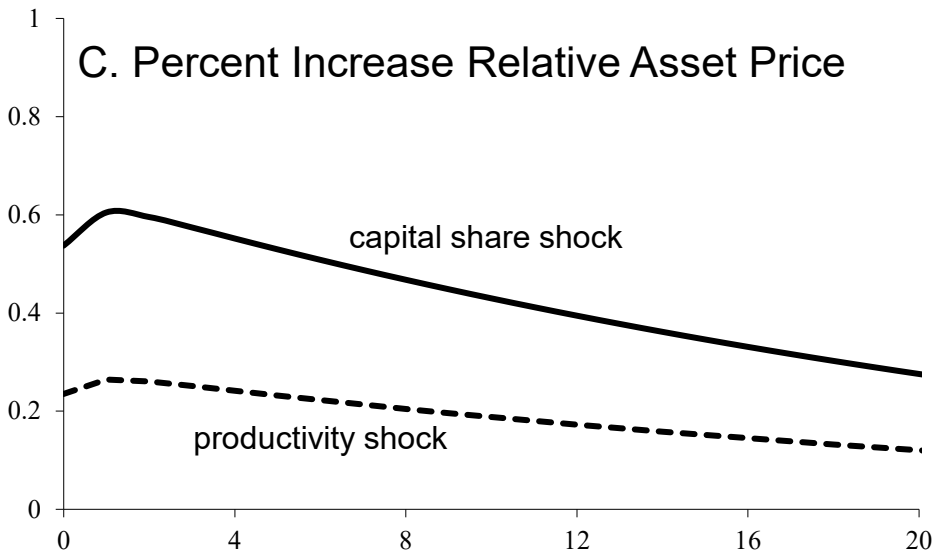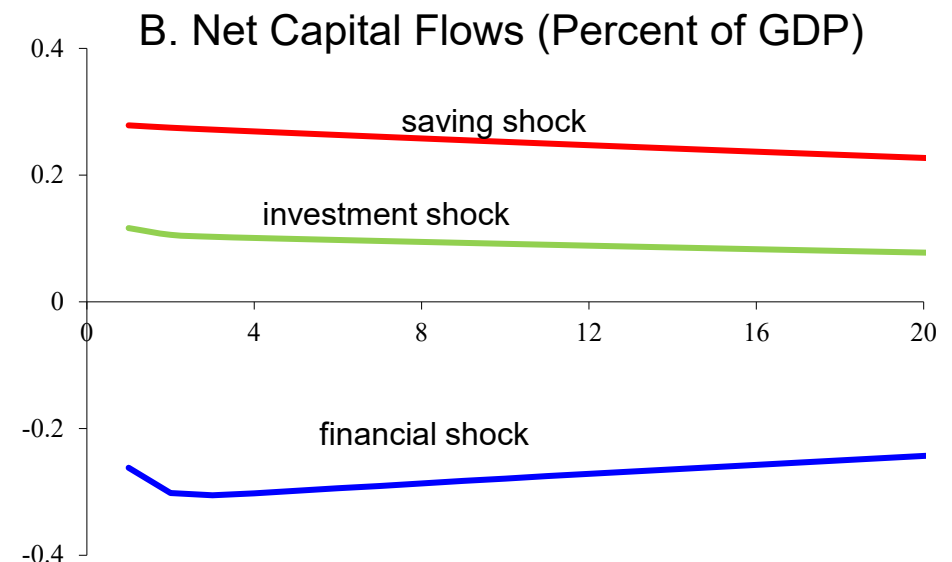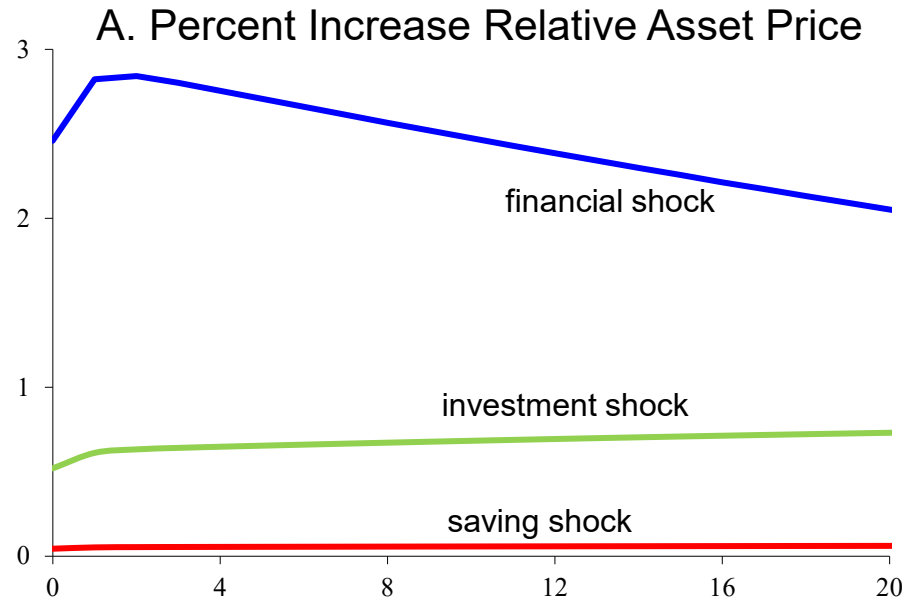## Table 3 Variance Decomposition

	(i) $\psi = 0$	(ii) $\psi = 1$	(iii) $\psi = 3$	(iv) $\psi = 0$ other param. as column (ii)	(v) $\psi = 3$
Excess Return					
financial shocks	87.1	90.7	94.1	0.0	99.1
dividend shocks	7.1	5.2	3.4	56.0	0.5
saving shocks	0.0	0.0	0.0	0.0	0.0
investment shocks	5.8	4.1	2.5	43.9	0.4
Current Account					
financial shocks	40.5	46.6	55.8	0.0	90.7
dividend shocks	0.8	0.9	1.0	1.5	0.2
saving shocks	53.3	47.9	39.8	90.8	8.0
investment shocks	5.4	4.6	3.5	7.7	1.1

Table 4 Sensitivity Analysis

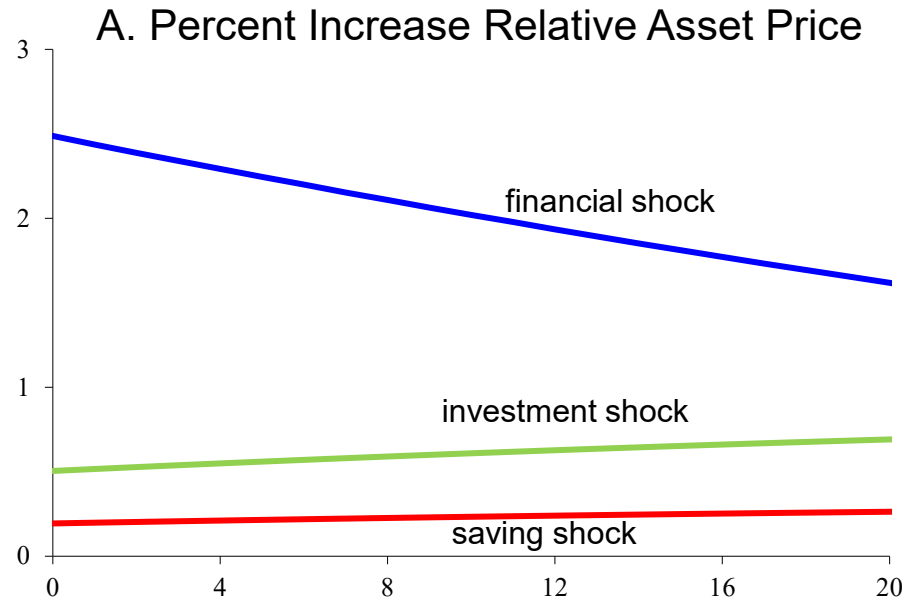|	Size Financial Shock			Price Impact M		
	$\psi = 0$	$\psi = 1$	$\psi = 3$	$\psi = 0$	$\psi = 1$	$\psi = 3$
baseline ($\gamma = 10$, $\rho_\tau = 0.99$)	0.2080	0.0166	0.0109	0.1173	1.4783	2.1786
$\gamma = 100$	0.0315	0.0081	0.0059	0.7887	3.061	4.036
$\rho_\tau = 0.95$	0.4893	0.0287	0.0165	0.0494	0.8517	1.4322
$\rho_\tau = 0.995$	0.1728	0.0144	0.0096	0.1414	1.7052	2.4548

Figure 1 Impulse Response Functions: $\psi=1$*

A. Percent Increase Relative Asset Price

financial shock

investment shock

saving shock

B. Net Capital Flows (Percent of GDP)

saving shock

investment shock

financial shock

C. Percent Increase Relative Asset Price

capital share shock

productivity shock

D. Net Capital Flows (Percent of GDP)
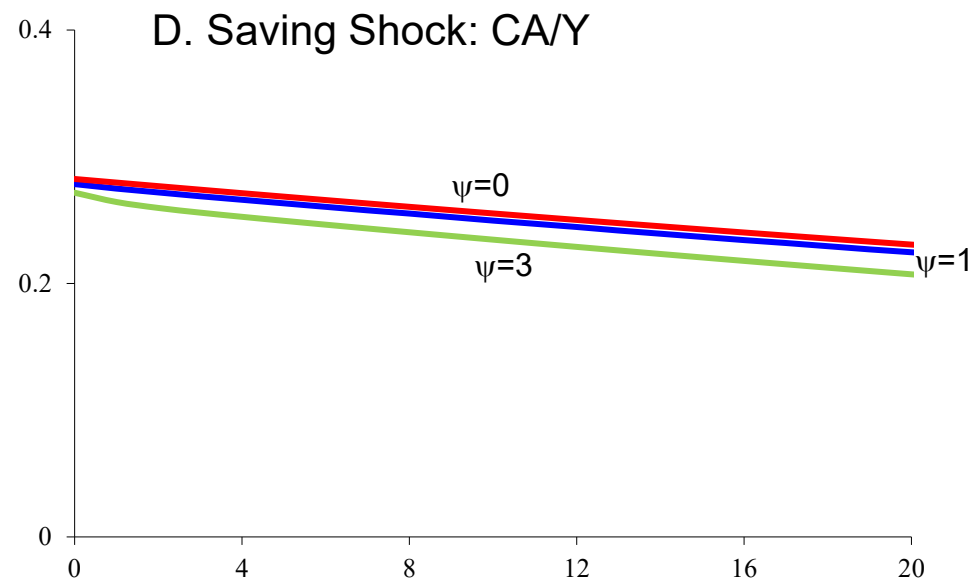
capital share shock

productivity shock

*Impulse response of relative asset price and CA/Y to one standard deviation shocks when $\psi=1$.
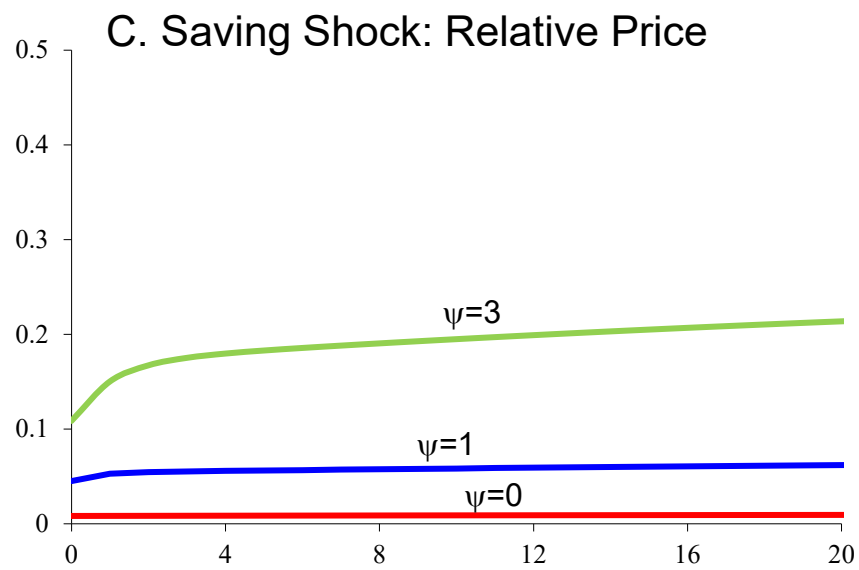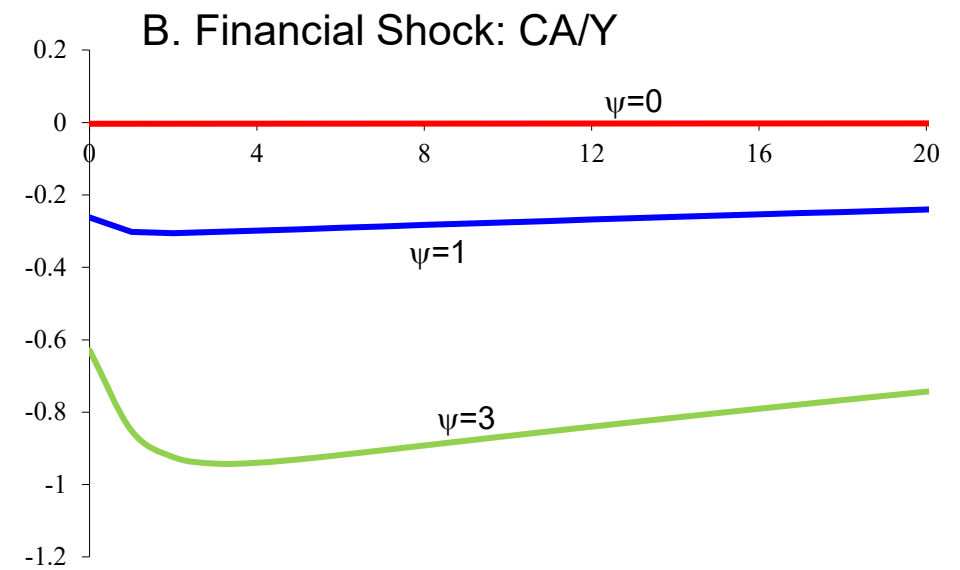
Figure 2 Impulse Response Functions: ψ=3*

A. Percent Increase Relative Asset Price

financial shock

investment shock

saving shock

B. Net Capital Flows (Percent of GDP)

saving shock

investment shock

financial shock

C. Percent Increase Relative Asset Price

capital share shock

productivity shock

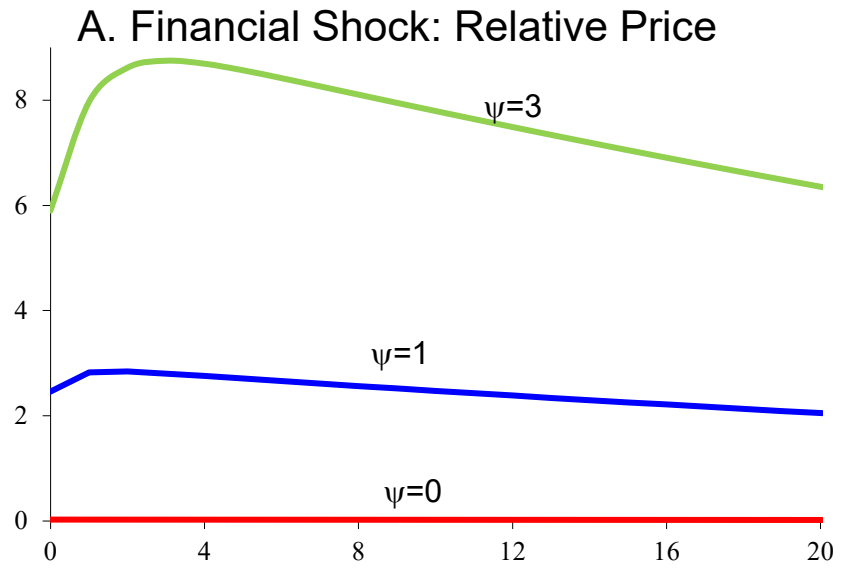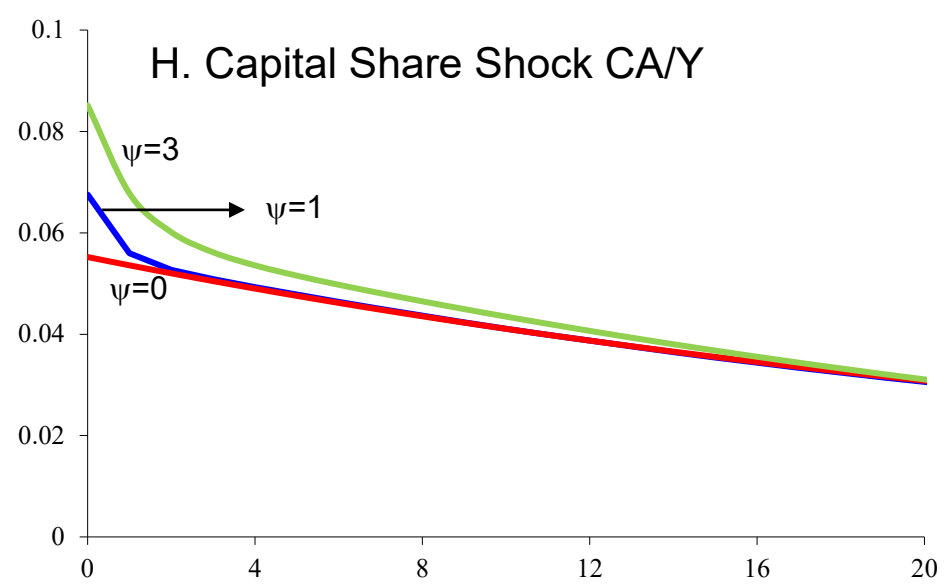D. Net Capital Flows (Percent of GDP)

capital share shock

productivity shock

*Impulse response of relative asset price and CA/Y to one standard deviation shocks when ψ=1.

Figure 3 Impulse Response Functions: ψ=0*

A. Percent Increase Relative Asset Price

financial shock

investment shock

saving shock

B. Net Capital Flows (Percent of GDP)

saving shock

investment shock

financial shock

C. Percent Increase Relative Asset Price

capital share shock

productivity shock

D. Net Capital Flows (Percent of GDP)
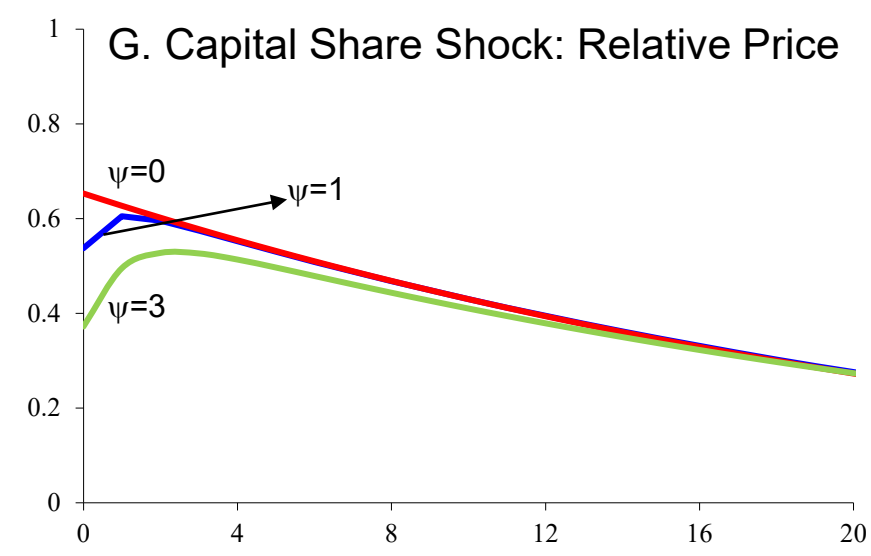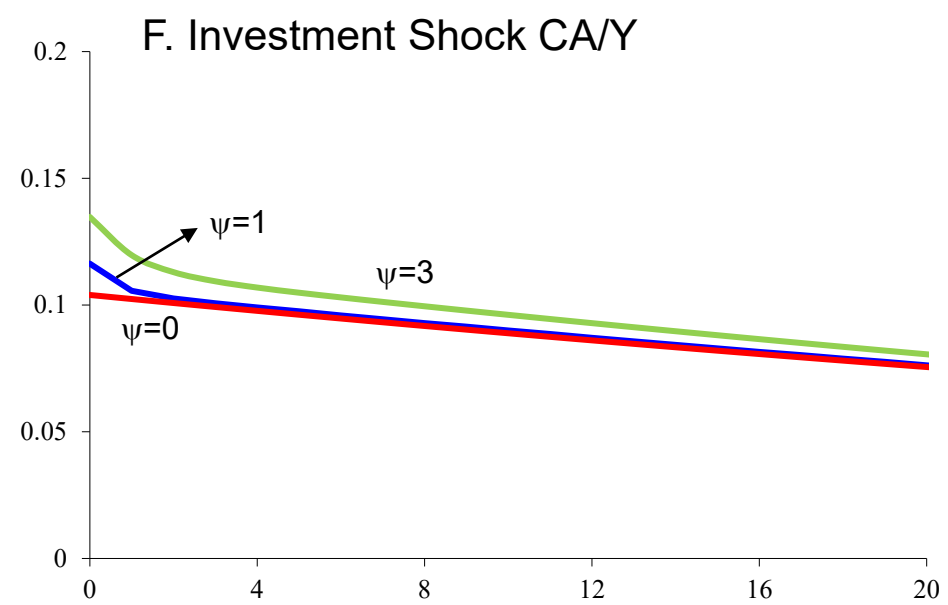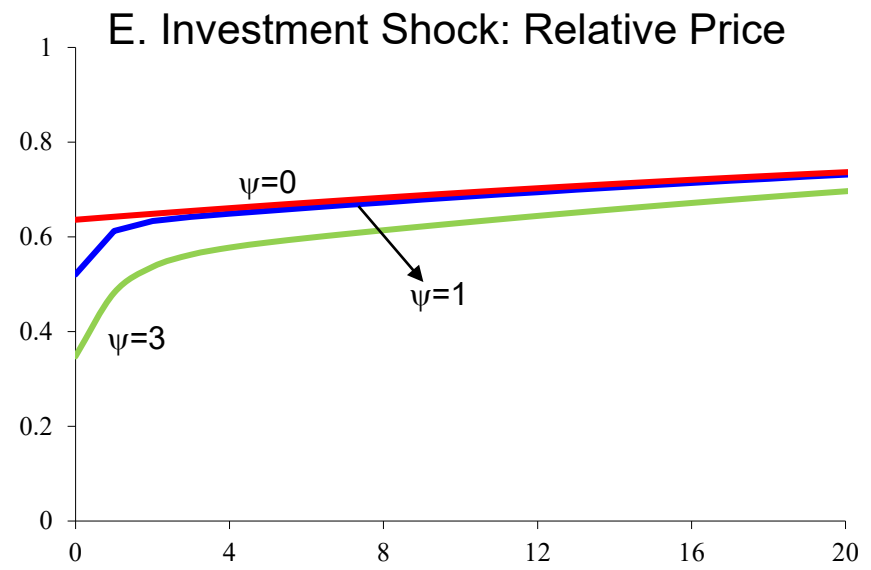
capital share shock

productivity shock

*Impulse response of relative asset price and CA/Y to one standard deviation shocks when ψ=1.

Figure 4 Impulse Response Functions: Impact Portfolio Friction ψ*

A. Financial Shock: Relative Price

ψ=3

ψ=1

ψ=0

B. Financial Shock: CA/Y

ψ=0

ψ=1

ψ=3

C. Saving Shock: Relative Price

ψ=3

ψ=1

ψ=0

D. Saving Shock: CA/Y

ψ=0

ψ=3

ψ=1

*Impulse response of relative asset price and CA/Y to one standard deviation shocks when ψ=1.

Figure 4 (continued) Impulse Response Functions: Impact Portfolio Friction ψ*

E. Investment Shock: Relative Price

F. Investment Shock CA/Y

G. Capital Share Shock: Relative Price

H. Capital Share Shock CA/Y

*Impulse response of relative asset price and CA/Y to one standard deviation shocks when ψ=1.