What Drives the Exchange Rate?*

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October 26, 2023

Abstract

We use a general open-economy wedge-accounting framework to characterize the set of shocks that can account for the major exchange rate puzzles. Focusing on a near-autarky behavior of the economy as a conservative limiting case, we show analytically that all standard macroeconomic shocks — including, productivity, monetary, government spending, and markups — are inconsistent with the broad properties of macro-exchange-rate disconnect. News shocks about these future macro-fundamental shocks generate plausible exchange rate properties, however, show up prominently in contemporaneous asset prices, thus violating the finance-exchange-rate disconnect. Furthermore, international shocks to trade costs, terms of trade and import demand, while potentially consistent with the disconnect properties, do not robustly generate the empirical Backus-Smith, UIP and terms-of-trade properties. In contrast, all exchange rate puzzles can be generated by financial shocks, provided they are transmitted via shifts in demand of foreign investors for home-currency assets.

*We thank Mark Aguiar, Andy Atkeson, Gita Gopinath, Pierre-Olivier Gourinchas, Maury Obstfeld, Kenneth Rogoff, Jón Steinsson, Adrien Verdelhan and seminar/conference participants for helpful comments, and Haonan Zhou for outstanding research assistance.

1 Introduction

Exchange rate disconnect is among the most challenging and persistent international macro puzzles. While this term narrowly refers to the lack of correlation between exchange rates and other macro variables, the broader puzzle is more pervasive and nests a number of additional empirical patterns, which stand at odds with conventional international macro models. This includes: First, the Meese and Rogoff (1983) puzzle that *nominal* exchange rates follow a volatile near-random-walk process and are not robustly correlated, even contemporaneously, with macroeconomic fundamentals.[1] Second, the PPP puzzle with real exchange rates moving almost one-to-one at most frequencies with nominal exchange rates (Rogoff 1996). Third, the Backus and Smith (1993) puzzle about a negative correlation between exchange rates and relative consumption, which contradicts the standard risk sharing logic. Fourth, the Forward premium puzzle about the deviations from the uncovered interest parity (UIP, Fama 1984). Finally, the financial disconnect puzzle that emphasizes the lack of correlation between exchange rates and asset prices (see e.g. Brandt, Cochrane, and Santa-Clara 2006).

In our previous work, we argue that introducing a currency demand shock to an otherwise conventional open economy model simultaneously solves all these puzzles (Itskhoki and Mukhin 2021a). The results are robust to different microfoundations of this financial shock and to the alternative general equilibrium structures ranging from international RBC model to sticky-price open economy.[2] However, this leaves open the question whether there are alternative shocks that can explain empirical patterns. There is no lack of potential candidates in the literature: persistent monetary and productivity shocks with a strong news component about future realizations (Engel and West 2005, Corsetti, Dedola, and Leduc 2008, Chahrour, Cormun, Leo, Guerron-Quintana, and Valchev 2022), relative productivity shocks in tradable and non-tradable sectors (Benigno and Thoenissen 2008), idiosyncratic income shocks across households (Kollmann 2012), discount factor shocks (Stockman and Tesar 1995, Eaton, Kortum,

[1] Note that we emphasize aggregate macroeconomic variables, such as GDP, aggregate consumption and overall CPI inflation. Macro exchange rate disconnect does not imply a lack of exchange rate correlation with all variables, as exchange rates may well, and even mechanically, correlate with trade prices and quantities in international goods and financial markets. There are also non-trivial conditional correlations with some aggregate macroeconomic and financial variables (Burstein and Gopinath 2012, Alessandria and Choi 2021, Gopinath, Boz, Casas, Díez, Gourinchas, and Plagborg-Møller 2020, Jiang, Krishnamurthy, and Lustig 2021, Lilley, Maggiori, Neiman, and Schreger 2022, Fukui, Nakamura, and Steinsson 2023).

[2] Models of financial shocks include both exogenous UIP shocks (see e.g. Devereux and Engel 2002, Kollmann 2005, Farhi and Werning 2012), which can be viewed to emerge from exogenous asset demand following Kouri (1976, 1983), and a variety of models of endogenous UIP deviations include models with incomplete information, expectational errors and heterogeneous beliefs (Evans and Lyons 2002, Gourinchas and Tornell 2004, Bacchetta and van Wincoop 2006, Burnside, Han, Hirshleifer, and Wang 2011), financial frictions (Adrian, Etula, and Shin 2015, Camanho, Hau, and Rey 2018), habits, long-run risk and rare disasters (Verdelhan 2010, Colacito and Croce 2013, Farhi and Gabaix 2016), as well as models of segmented financial markets Jeanne and Rose (2002), Alvarez, Atkeson, and Kehoe (2009), Gabaix and Maggiori (2015), Itskhoki and Mukhin (2021b).

and Neiman 2015), long-run risk (Colacito and Croce 2011), and shocks that manifest themselves as the labor wedge (Karabarbounis 2014). Equally important, there is a question about what kind of financial shocks can generate volatile and disconnected movements in exchange rates without a strong impact on other financial market variables.

In this paper, we address these questions, refine the set of potential candidates for financial shocks, and show that they are not only *sufficient* to solve the exchange rate disconnect, but are also *necessary*. Our work builds on the seminal contribution of Obstfeld and Rogoff (2001) who show that home bias is crucial to solve many international puzzles (mostly unrelated to the exchange rate disconnect). Leveraging this insight, we consider a near-autarky behavior of the economy, and require that the shock process produces a volatile exchange rate behavior with a vanishing effect on the economy's aggregate quantities and prices, as the economy becomes closed to trade. Indeed, in the limit of the closed economy, any exchange rate volatility (real or nominal) should be completely inconsequential for allocations. Not surprisingly, productivity and monetary shocks, as well as the majority of other shocks, violate this intuitive requirement. This explains why standard open economy models fail to generate the exchange rate disconnect. Instead, we show that the one shock that satisfies this requirement, and additionally produces the empirically relevant signs of comovement between exchange rates and macro variables (including consumption and interest rates), is the shock to the international asset demand.

We then bring the disconnect between exchange rates and asset prices in the data and leverage these moments to further sharpen the results. In particular, we show that the news shocks about future macro fundamentals are unlikely to be the main drivers of exchange rates as those shocks also affect asset prices through their effect on future returns and the stochastic discount factor. Indeed, both asset prices and exchange rates (under incomplete markets) are forward looking and incorporate information about agents' expectations. As long as the asset markets are sufficiently rich, it is not possible to find a combination of news shocks that move exchange rates, yet have no effect on any asset price. Furthermore, the same approach allows us to refine the set of asset demand shocks that are the most likely candidates to explain the disconnect. To this end, we focus on assets with returns that do not directly depend on exchange rates or other international variables. The prices of such assets in a local currency are pinned down by domestic investors and any local demand shocks are mostly absorbed by asset prices. In contrast, the only way to equilibrate the market in response to foreign demand shock for home assets involves movements in the exchange rate. In response to such shocks, an appreciation of the home currency on impact and the ensuing expected depreciation both act to discourage foreign investors from increasing their holdings of home assets, bringing the market back to equilibrium.

The rest of the paper is organized as follows. Section 2 describes the modeling framework and the set of shocks. Section 3 defines formally the exchange rate disconnect in the autarky limit. Subsection 3.1 focuses on the macroeconomic variables and proves that financial shocks broadly defined are the most likely candidates to explain empirical moments. Subsection 3.2 then refines the argument and shows that these shocks cannot be interpreted as news about future macro fundamentals and that only demand shocks for particular assets of particular investors can generate the disconnect. Appendix A summarize the entire equilibrium system and provides detailed derivations and proofs.

2 Modeling Framework

We start with a flexible modelling framework that nests most standard international macro models. There are two countries, home (Europe) and foreign (US, denoted with a $*$). Each country has its nominal unit of account, in which the local prices are quoted. In particular, the home wage rate is W_t euros and the foreign wage rate is W_t^* dollars. The nominal exchange rate $\mathcal{E}_t$ is the price of dollars in terms of euros, hence an increase in $\mathcal{E}_t$ signifies a nominal devaluation of the euro (the home currency). We allow for a variety of shocks hitting the economy and proxying in some cases for unmodelled market imperfections. We then explore which of these disturbances can account for the exchange rate disconnect, as we formally define it below in Section 3.

Households maximize the discounted expected utility over consumption and labor:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t e^{\chi_t} \left(\frac{1}{1-\sigma} C_t^{1-\sigma} - \frac{e^{\kappa_t}}{1+1/\varphi} L_t^{1+1/\varphi} \right), \tag{1}$$

where σ is the relative risk aversion parameter, φ is the Frisch elasticity of labor supply, and χ_t and κ_t are the utility shifters (shocks). The flow budget constraint is given by:

$$P_t C_t + \sum_{j \in J_t} \Theta_t^j B_{t+1}^j \leq \sum_{j \in J_{t-1}} e^{-\psi_t^j} (\Theta_t^j + \mathcal{D}_t^j) B_t^j + W_t L_t + \Pi_t + T_t, \tag{2}$$

where P_t is the consumer price index, W_t is the nominal wage rate, Π_t are profits of home firms, T_t are lump-sum transfers from the government. B_{t+1}^j is the quantity of asset $j \in J_t$ purchased at time t at price Θ_t^j with a state-contingent pay-out $\mathcal{D}_{t+1}^j$ at $t+1$ and taxed at a state-contingent rate ψ_{t+1}^j. Without loss of generality, we assume that all assets are in zero net supply: the households receive profits of local firms, but can issue equity and sell it to foreigners.

The households are active in three markets. First, they supply labor according to the standard static optimality condition:

$$e^{\kappa_t} C_t^{\sigma} L_t^{1/\varphi} = \frac{W_t}{P_t}, \tag{3}$$

where the preference shock κ_t can be alternatively interpreted as the *labor wedge*, playing an important role in the closed-economy business cycle literature and capturing the departures from the neoclassical labor market dynamics due to search frictions or sticky wages (see e.g. Chari, Kehoe, and McGrattan 2007, Shimer 2009).

Second, the households allocate their within-period expenditure between home and foreign goods:

$$P_t C_t = P_{Ht} C_{Ht} + P_{Ft} C_{Ft}.$$

For simplicity, we assume preferences with a constant elasticity of substitution, although our results generalize to any homothetic demand:[3]

$$C_{Ht} = (1-\gamma) e^{-\gamma \xi_t} \left(\frac{P_{Ht}}{P_t} \right)^{-\theta} C_t \qquad \text{and} \qquad C_{Ft} = \gamma e^{(1-\gamma)\xi_t} \left(\frac{P_{Ft}}{P_t} \right)^{-\theta} C_t, \tag{4}$$

where the ideal price index is given by $P_t = \left[(1-\gamma) P_{Ht}^{1-\theta} + \gamma P_{Ft}^{1-\theta} \right]^{\frac{1}{1-\theta}}$, ξ_t is the relative demand shock for the foreign good (as in Pavlova and Rigobon 2007), θ is the elasticity of substitution between home and foreign goods, and $1-\gamma$ captures the *home bias*, which can be due to a combination of home bias in preferences, trade costs and non-tradable goods (see Obstfeld and Rogoff 2001). We write the consumer price level as $P_t \equiv e^{p_t}$ and interpret p_t as the shock to the nominal value of the local unit of account (numeraire), which captures monetary shocks in our framework.

Lastly, the households choose their asset positions according to the dynamic optimality conditions:

$$\beta \mathbb{E}_t \left\{ e^{\Delta \chi_{t+1} - \psi_{t+1}^j} \left(\frac{C_{t+1}}{C_t} \right)^{-\sigma} \frac{P_t}{P_{t+1}} \frac{\Theta_{t+1}^j + \mathcal{D}_{t+1}^j}{\Theta_t^j} \right\} = 1. \tag{5}$$

Notice that a preference shock that is uniform across all assets $\psi_t^j = \psi_t$ affects the consumption-savings decision and acts as an overall savings shock χ_t in (1), as in Stockman and Tesar (1995). For this reason, we normalize $\chi_t \equiv 0$ without loss of generality. In contrast, differential shocks ψ_t^j across j act as relative asset demand shifters that affect the portfolio choice.

[3] Introducing demand shocks ξ_t in this way ensures that they only shift demand for home versus foreign goods, but to the first order of approximation do not affect the aggregate price index given by $p_t = (1-\gamma)p_{Ht} + \gamma p_{Ft}$.

Production and prices Output is produced by a given pool of identical firms with a linear technology

$$Y_t = e^{a_t} L_t. \tag{6}$$

For analytical tractability, we focus on a constant-returns-to-scale production without capital or intermediate inputs, which are subsumed by a productivity wedge a_t (see Itskhoki and Mukhin 2021a). Therefore, the marginal cost of production is:

$$MC_t = e^{-a_t} W_t. \tag{7}$$

The total production of domestic firms is divided between the home and foreign markets, $Y_t = Y_{Ht} + Y^*_{Ht}$, resulting in profits that are distributed to the domestic households:[4]

$$\Pi_t = (P_{Ht} - MC_t)\, Y_{Ht} + (P^*_{Ht}\mathcal{E}_t - MC_t)\, Y^*_{Ht}. \tag{8}$$

We postulate the following price setting:

$$P_{Ht} = e^{\mu_t} MC_t, \qquad\qquad P^*_{Ht} = e^{\mu_t+\eta_t} MC_t/\mathcal{E}_t, \tag{9}$$

where μ_t is the markup shock and η_t is the law of one price (LOP) shock. Given these prices, the firms satisfy the resulting demand in both markets. Equations (9) are *ad hoc* yet general pricing equations, as the markup terms allow them to be consistent with a broad range of price setting models, including both monopolistic and oligopolistic competition models under both CES and non-CES demand. Furthermore, if the time path of (μ_t, η_t) is not restricted, these equations are also consistent with dynamic price setting models, and in particular the sticky price models (with either producer, local or dollar currency pricing).[5]

Government uses lump-sum taxes to finance an exogenous stochastic path of government expenditure $G_t \equiv e^{g_t}$, where g_t is the government spending shock. For simplicity, we assume that government expenditure is allocated between the home and foreign goods in the same way as the final consumption in (4). The government collects taxes on the financial positions of domestic households and returns net income lump sum to households to run a balanced

[4]We assume no entry or exit of firms, as our model is a medium-run one (for the horizons of up to 5 years), where empirically extensive margins play negligible roles (see e.g. Bernard, Jensen, Redding, and Schott 2009).

[5]Note that η_t can stand in for a trade cost shock, which plays a central role in the recent quantitative analyses of Eaton, Kortum, and Neiman (2015), Reyes-Heroles (2016), Alessandria and Choi (2021) and Mac Mullen and Woo (2023). A combination of η_t and ξ_t can also stand in for a world commodity price shock, acting as a wealth transfer between countries. These shocks are an important source of volatility for the commodity-exporting and also commodity-importing countries (see e.g. Chen and Rogoff 2003, Ayres, Hevia, and Nicolini 2020).

budget, which in view of Ricardian equivalence is without loss of generality:[6]

$$T_t = \sum_{j \in J_{t-1}} (1 - e^{-\psi_t^j})(\Theta_t^j + \mathcal{D}_t^j) B_t^j - P_t e^{g_t}. \tag{10}$$

Foreign households are symmetric, except that their asset choice set is J_t^* and in general different from J_t. Their budget constraint is given by:

$$P_t^* C_t^* + \sum_{j \in J_t^*} \frac{\Theta_t^j}{\mathcal{E}_t} B_{t+1}^{*j} \leq \sum_{j \in J_{t-1}^*} e^{-\psi_t^{*j}} \frac{\Theta_t^j + \mathcal{D}_t^j}{\mathcal{E}_t} B_t^{*j} + W_t^* L_t^* + \Pi_t^* + T_t^*,$$

where the nominal exchange rate $\mathcal{E}_t$ converts prices and dividends of assets into foreign currency. The optimal savings and portfolio choice decisions of the foreign households are characterized by the Euler equations:

$$\beta \mathbb{E}_t \left\{ e^{\Delta \chi_{t+1}^* - \psi_{t+1}^{*j}} \left(\frac{C_{t+1}^*}{C_t^*} \right)^{-\sigma} \frac{P_t^*}{P_{t+1}^*} \frac{\Theta_{t+1}^j + \mathcal{D}_{t+1}^j}{\Theta_t^j} \frac{\mathcal{E}_t}{\mathcal{E}_{t+1}} \right\} = 1. \tag{11}$$

The foreign households supply labor and demand home and foreign goods according to the optimality condition parallel to (3) and (4) respectively. In particular, the goods demand by the foreign households is given by:

$$C_{Ht}^* = \gamma e^{(1-\gamma)\xi_t^*} \left(\frac{P_{Ht}^*}{P_t^*} \right)^{-\theta} C_t^* \qquad \text{and} \qquad C_{Ft}^* = (1-\gamma) e^{-\gamma \xi_t^*} \left(\frac{P_{Ft}^*}{P_t^*} \right)^{-\theta} C_t^*, \tag{12}$$

where ξ_t^* is the foreign demand shock for home goods. Lastly, the foreign firms are also symmetric, demand foreign labor, and charge prices according to the counterparts of (9) with their own markup and LOP shocks μ_t^* and η_t^*, as we detail in Appendix A.1.

Equilibrium conditions ensure that the asset, product and labor markets clear and the intertemporal budget constraints of the countries are satisfied. The labor market clears when L_t is consistent simultaneously with labor supply in (3) and labor demand in (6), and symmetri-

[6]The wedge g_t also subsumes any expenditures on investment that arise in a model with endogenous capital dynamics.

Table 1: Model parameters and shocks

Shocks		Parameters	
p_t	monetary shock to price level	$\beta = 0.99$	discount factor
a_t	productivity shock	$\sigma = 2$	relative risk aversion (inverse of IES)
κ_t	labor wedge (sticky wages)	$\varphi = 1$	Frisch elasticity of labor supply
ξ_t	international good demand shock	$\gamma = 0.15$	foreign share (home bias) parameter
g_t	government spending shock	$\theta = 1.5$	elasticity of substitution
μ_t	markup shock (sticky prices)	$\rho = 0.97$	persistence of shocks
η_t	law-of-one-price shock (LCP/DCP, trade costs)		
ψ_t^j	financial (asset demand) shocks		

Note: the left panel summarizes the shocks to the home economy, with foreign facing a symmetric set of shocks; the right panel reports the baseline parameter values.

cally for L_t^* in foreign. The goods market clearing requires $Y_t = Y_{Ht} + Y_{Ht}^*$, where

$$Y_{Ht} = C_{Ht} + G_{Ht} = (1-\gamma)e^{-\gamma\xi_t}\left(\frac{P_{Ht}}{P_t}\right)^{-\theta}[C_t + G_t], \tag{13}$$

$$Y_{Ht}^* = C_{Ht}^* + G_{Ht}^* = \gamma e^{(1-\gamma)\xi_t^*}\left(\frac{P_{Ht}^*}{P_t^*}\right)^{-\theta}[C_t^* + G_t^*], \tag{14}$$

and symmetric conditions hold for $Y_{Ft} + Y_{Ft}^* = Y_t^*$. Because all assets are in zero net supply, market clearing requires that

$$B_t^j + B_t^{*j} = 0 \qquad \text{for} \quad j \in J_{t-1} \cap J_{t-1}^* \tag{15}$$

and $B_t^j = B_t^{*j} = 0$ for all other assets that are not traded internationally.

Lastly, we combine the household budget constraint (2) with profits (8) and the government budget constraint (10) to derive the country budget constraint:

$$\sum_{j\in J_t} \Theta_t^j B_{t+1}^j - \sum_{j\in J_{t-1}} (\Theta_t^j + \mathcal{D}_t^j) B_t^j = NX_t, \qquad \text{where} \quad NX_t = \mathcal{E}_t P_{Ht}^* Y_{Ht}^* - P_{Ft} Y_{Ft} \tag{16}$$

is net exports of the home country (in home currency).

The *real exchange rate* $\mathcal{Q}_t$ is defined conventionally as the relative price of consumption baskets across the two markets and the *terms of trade* are given by the relative price at which the home country exchanges its exports for imports:

$$\mathcal{Q}_t \equiv \frac{P_t^* \mathcal{E}_t}{P_t} \qquad \text{and} \qquad \mathcal{S}_t \equiv \frac{P_{Ft}}{P_{Ht}^* \mathcal{E}_t}. \tag{17}$$

Shocks are summarizes in Table 1, along with the parameters of the model and their standard values, which we use in our numerical illustrations. In general, we allow shocks to follow arbitrary joint stochastic processes with unrestricted patterns of covariation. In this sense, our shocks are not primitive innovations, but rather disturbances to the equilibrium conditions of the model, akin to Chari, Kehoe, and McGrattan (2007) *wedges*.[7] We use them differently, however. Instead of accounting for the sources of variation in the macro variables, we prove theoretical results characterizing which subsets of disturbances can and cannot result in an equilibrium *disconnect* behavior of the exchange rates, as defined below.

3 Disconnect in the Limit

This section provides several theoretical results that narrow down the set of shocks that can be consistent with the empirical exchange rate disconnect properties. The key methodological contribution that allows us to make progress in answering this question is the focus on the equilibrium system around the autarky limit. The limit with the share of foreign goods in consumption converging to zero $\gamma \to 0$ is interesting for two reasons.

First, a full trade autarky $\gamma = 0$ offers a model of *complete exchange rate disconnect*. Although financial markets can still potentially pin down the level of the nominal exchange rate, its value is of no consequence for macroeconomic variables (the Meese-Rogoff puzzle). Since price levels do not respond to this volatility, the real exchange rate comoves perfectly with these nominal exchange rate shocks, and as a result can exhibit arbitrary volatility and persistence (the PPP puzzle).

Second, away from autarky, the response of macro variables to exchange rate tends to increase together with the degree of openness γ, resulting in more volatile and less disconnected macroeconomic behavior. Therefore, if the economy does not exhibit exchange rate disconnect properties near autarky (for $\gamma \approx 0$), it is unlikely to feature them away from autarky (for $\gamma \gg 0$). In addition, $\gamma \approx 0$ is not an unreasonable point of approximation for countries with the most pronounced disconnect between macro variables and exchange rates. Indeed, the ratio of imports to GDP is around 15% for the U.S., Eurozone, and Japan, and is even lower if estimated as an average over the period of free-floating exchange rates since 1973.[8] The empirical literature finds that more open economies have less volatile exchange rates, even after

[7]For example, Eaton, Kortum, and Neiman (2015) is a recent study, which uses wedge accounting in the international context. Our approach differs in that we do not attempt to fully match macroeconomic time series, but instead focus on a specific theoretical mechanism which accounts for a set of exchange rate disconnect moments within a parsimonious model. This is also what sets our paper apart from the international DSGE literature following Eichenbaum and Evans (1995).

[8]This contrasts with the financial openness of economies: given that the gross assets and liabilities of countries often exceed their annual GDP, a *financial* autarky is hardly an accurate point of approximation.

controlling for country size and other characteristics (e.g., Hau 2002) — a pattern reproduced by our model (Itskhoki and Mukhin 2021a).

We now extend the autarky logic to study circumstances under which a near-closed economy features a *near-complete exchange rate disconnect* and argue that this continuity requirement offers a sharp selection criterion for exogenous shocks.

3.1 Macro Disconnect

Our first set of results focuses on the disconnect between exchange rates and macroeconomic variables in the autarky limit, which we formalize as follows:

Definition 1 (Macro disconnect in the limit) *Denote with $\mathbf{Z}_t \equiv (W_t, P_t, C_t, L_t, Y_t)$ a vector of all domestic macro variables (wage rate, price level, consumption, employment, output) and with $\varepsilon_t \equiv \mathbf{V}'\Omega_t + \mathbf{V}^{*\prime}\Omega_t^*$ an arbitrary combination of shocks $\Omega_t = \{p_t, \kappa_t, a_t, g_t, \mu_t, \eta_t, \xi_t, \psi_t^j\}$. We say that an open economy (with $\gamma > 0$) exhibits macro disconnect in the autarky limit if*

$$\lim_{\gamma\to 0} \frac{\mathrm{d}\mathbf{Z}_t}{\mathrm{d}\varepsilon_t} = 0 \qquad \textit{and} \qquad \lim_{\gamma\to 0} \frac{\mathrm{d}\mathcal{E}_t}{\mathrm{d}\varepsilon_t} \neq 0. \tag{18}$$

A corollary of condition (18) is that $\lim_{\gamma\to 0}[\mathrm{d}\log\mathcal{E}_t - \mathrm{d}\log\mathcal{Q}_t]/\mathrm{d}\varepsilon_t = 0$.

In words, a model, defined by its structure and the set of shocks, exhibits exchange rate disconnect in the autarky limit if the shocks have a vanishingly small effect on the macro variables, yet result in a volatile equilibrium exchange rate. This property captures the disconnect in its narrow Meese-Rogoff sense. However, as the corollary points out, this property also implies the PPP-puzzle behavior for the real exchange rate, which in the limit comoves one-for-one with the nominal exchange rate.

Following the wedge accounting tradition, we assume for now that the baseline asset markets are complete and, with a slight abuse of notation, let $\Delta\zeta_t = \tilde{\psi}_t \equiv \psi_t^j - \psi_t^{*j}$ for all j with $\zeta_{-1} = 0$ denote the risk-sharing wedges in the Backus-Smith condition:

$$\mathcal{Q}_t = \Lambda e^{\zeta_t} \left(\frac{C_t}{C_t^*}\right)^{\sigma}, \tag{19}$$

where a time-invariant constant Λ is pinned down by the country's intertemporal budget constraint and is equal to one in the case of symmetric economies. This approach allows us to disentangle the direct effects of shocks from their "news component". The next section goes back to more general asset markets and discusses endogenous deviations from full risk sharing under incomplete markets that arise due to news shocks about future fundamentals.

Definition 1 allows us to exclude a large number of candidate shocks by proving the following result:[9]

Proposition 1 *The model of Section 2 cannot exhibit macro disconnect in the autarky limit* (18) *if the combined shock ε_t in Definition 1 has a weight of zero on the subset of shocks $\{\eta_t, \eta_t^*, \xi_t, \xi_t^*, \tilde{\psi}_t\}$.*

In other words, this proposition states that the shocks in $\Omega_t^{\varnothing} \equiv \{p_t, \kappa_t, a_t, g_t, \mu_t\}$ together with their foreign counterparts, in any combinations and with arbitrary cross-correlations, cannot reproduce an exchange rate disconnect property even as the economy approaches autarky. We provide a formal proof in Appendix A.2, yet the intuition behind this result is straightforward. Any of the shocks in $\Omega_t^{\varnothing}$ will have a direct effect on real allocations, prices, and/or interest rates, and thus cannot result in a volatile exchange rate without having a direct effect on the macro variables of the same order of magnitude.

Intuitively, the unit of account p_t shocks result in price inflation, the markup μ_t shocks result in wage deflation, the labor wedge κ_t shocks result in changes in either employment or consumption, the productivity a_t shocks result in changes in either employment or output, and the government spending g_t shocks result in changes in either consumption or output. Furthermore, our proof establishes that there is no combination of such shocks that can simultaneously net out in their effects on macro variables, but not on the exchange rate. Therefore, as an economy subject to these shocks approaches autarky, the disconnect property (18) is necessarily violated.

Figure 1 illustrates this result by showing the volatility of macro variables relative to the volatility of the exchange rate for different values of openness γ. Consistent with Proposition 1, the relative volatility does not converge to zero for any shock from $\Omega_t^{\varnothing}$. Furthermore, the exchange rate "connect" becomes even more pronounced as γ increases and the economy moves further away from the autarky limit, confirming the validity of our focus on the near-autarky behavior of the economy.

We view Proposition 1 as an "order-of-magnitude" result. Since exchange rate volatility is about an order of magnitude larger than the volatility of the aggregate macro variables — with a 10–12 point versus 1–2 point annualized standard deviation in log changes — Definition 1 requires a qualitatively different volatility for the exchange rate in the limit. This is meant to proxy for a large volatility difference away from the autarky limit (for $\gamma > 0$ but perhaps $\gamma \approx 0$), as observed in the data. Furthermore, in a calibrated model, the quantitative properties of macroeconomic shocks in $\Omega_t^{\varnothing}$ tend to produce the exchange rate volatility of the same order of magnitude as macroeconomic volatility, as we establish in greater detail in Itskhoki and Mukhin (2021a) for productivity and monetary shocks.

[9] The proof of this proposition does not rely on the international risk sharing condition, and therefore this result is robust to the assumption about (in)completeness of the international asset market.

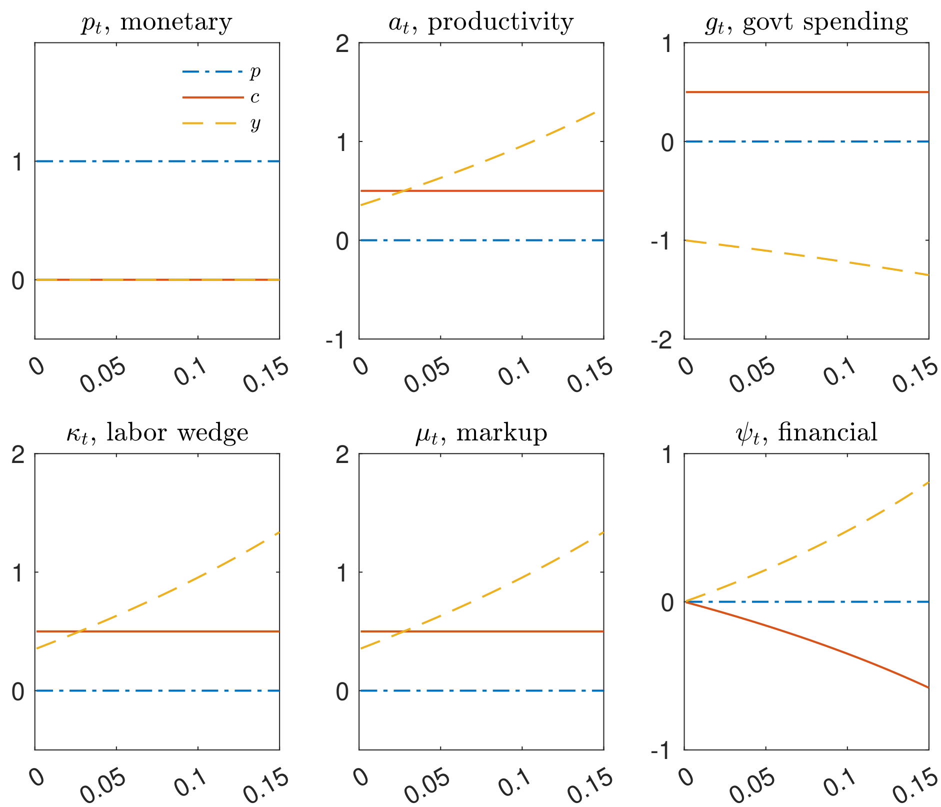

Figure 1: Relative macro-to-exchange rate impulse responses to shocks as a function of openness γ

Note: The figure plots $\frac{\mathrm{d}z_t}{\mathrm{d}e_t} \equiv \frac{\partial z_t/\partial \varepsilon_t}{\partial e_t/\partial \varepsilon_t}$ for three variables $z_t \in \{p_t - p_t^*, c_t - c_t^*, y_t - y_t^*\}$ (relative price level, relative consumption and relative output respectively) and shocks $\varepsilon_t \in \Omega_t = \{p_t, a_t, g_t, \kappa_t, \mu_t, \psi_t\}$ across models with different home bias parameter $\gamma \in [0, 0.15]$ and the other parameters as in Table 1. For financial shock ψ_t, the impulse responses for all three x_t are negligible relative to e_t in the autarky limit ($\gamma \to 0$), and tend to monotonically depart away from zero with $\gamma > 0$. For the other five shocks $(p_t, a_t, g_t, \kappa_t, \mu_t)$, the impulse response for at least one z_t is of the same order of magnitude as that for e_t, even near $\gamma = 0$.

Proposition 1 can be viewed as pessimistic news for both the International RBC and the New Open Economy Macro (NOEM) models of the exchange rate. It does *not* imply, however, that productivity cannot be an important source of exogenous shocks. Instead, it suggests that productivity shocks a_t are unlikely to be the dominant drivers of exchange rate movements if the model is to exhibit the exchange rate disconnect. The same applies to monetary shocks under both flexible and sticky prices. These shock can still be the key drivers of macroeconomic variables without violating the exchange rate disconnect property so long as some other shocks account for the bulk of the exchange rate volatility.

Therefore, we consider next the other three types of shocks — namely, the LOP deviation (or trade cost) shock η_t, the international good demand shock ξ_t, and/or the financial shock $\tilde{\psi}_t$ — as the likely key drivers of the exchange rate dynamics. The distinctive feature of these shocks is that they affect the equilibrium system exclusively through the *international equilibrium conditions*: $\tilde{\psi}_t$ affects international risk sharing (19), while η_t and ξ_t affect the country budget constraint (16) through their impact on export prices (9) and export demand (14), respectively.[10] The impact of shocks to these equilibrium conditions on the macro variables is vanishingly small as the economy becomes closed to international trade in goods and assets, yet such shocks can have substantial effect on the equilibrium exchange rates and terms of trade even when γ is close to zero.

Proposition 1 does not allow us to discriminate between the remaining three types of shocks, as they all satisfy the autarky-limit disconnect condition (18). Yet, these shocks differ in the implied comovement between exchange rates and macro variables, which we now use as a further selection criterion. In particular, we explore the comovement between the exchange rates and respectively terms of trade, relative consumption, and the interest rate differential, near the autarky limit (as $\gamma \to 0$). Since these shocks are already consistent with the Meese-Rogoff and the PPP puzzles by virtue of Proposition 1, the additional moments correspond to the three additional exchange rate puzzles — namely, the Backus-Smith puzzle and the Forward Premium (UIP) puzzle, as well the Terms of Trade puzzle emphasizing weak positive comovement of the terms of trade with the exchange rate (Engel 1999, Atkeson and Burstein 2008, Gopinath, Boz, Casas, Díez, Gourinchas, and Plagborg-Møller 2020).

We prove the following result (see Appendix A.2):

Proposition 2 *Near the autarky limit (for $\gamma \to 0$), the international asset demand shock $\tilde{\psi}_t$ is the only shock in $\{\eta_t, \eta_t^*, \xi_t, \xi_t^*, \tilde{\psi}_t\}$ that simultaneously and robustly produces:*

(i) *a positive correlation between the terms of trade and the real exchange rate;*

(ii) *a negative correlation between relative consumption growth and the real exchange rate depreciation;*

(iii) *deviations from UIP and a negative Fama coefficient.*

The main conclusion is that both the LOP deviation (trade cost) shock η_t and the international good demand shock ξ_t produce the *counterfactual* comovement between exchange rate changes and respectively the relative consumption growth (the Backus-Smith puzzle) and the interest rate differential (the Forward Premium puzzle). The financial shock $\tilde{\psi}_t$ is instead consistent with both of these empirical patterns. Combined together, Propositions 1 and 2 explain why most shocks cannot reproduce the empirical exchange rate properties, and hence why these properties are labeled as *puzzles* in the literature. These propositions favor the financial

[10]The ξ_t and η_t shocks are additionally featured in the goods market clearing (13)–(14) and in aggregate price indices, but in both cases their effect on these conditions is proportional to trade openness γ, and thus vanishes in the autarky limit.

shock $\tilde{\psi}_t$ as the likely shock to generate exchange rate disconnect in an equilibrium model. While these propositions are concerned with the autarky limit, the continuity of the model in trade openness γ suggests that the near-disconnect properties of the financial shock should hold for $\gamma > 0$ provided it is not too large.

3.2 Finance Disconnect

The two propositions above point to the deviations from complete risk sharing as the key source of exchange rate volatility. This section further narrows down the potential sources of these wedges and answers the following questions. First, can news shocks about future macro fundamentals under incomplete asset markets generate the risk-sharing wedges and account for exchange rate volatility? Second, which asset demand shocks are more likely to explain movements in exchange rates? To make progress, we bring in additional moments from financial markets and, in particular, the disconnect between exchange rates and asset prices, which is nearly as pronounced in the data as the disconnect between exchange rates and macro variables (Chernov and Creal 2023, Lustig and Verdelhan 2019, Chernov, Haddad, and Itskhoki 2023). We also keep the autarky limit as the diagnostic tool.

To this end, consider again a general structure of financial markets and define the class of assets $j \in \mathcal{A}$ with the payoff in home currency $\mathcal{D}_t^j$ statistically independent of the international variables $\{\mathcal{E}_t, B_t^j, B_t^{*j}, \eta_t, \eta_t^*, \xi_t, \xi_t^*, \psi_t^j, \psi_t^{*j}\}$. Symmetrically, define the class of assets $j \in \mathcal{A}^*$ with payoffs in foreign currency $\mathcal{D}_t^j/\mathcal{E}_t$ independent of the same endogenous variables and shocks. Intuitively, the definitions require that the payoffs do not directly or indirectly in the autarky limit depend on the exchange rate. Of course, this property can only be satisfied in one currency — once converted in the other currency, the dividends mechanically correlate with the exchange rate. In practice, this is expected to be a large class of assets that includes nominal and real bonds of different maturities, most equities of local firms, as well as any derivatives of these bonds and equities. Notice that the definition allows $\mathcal{D}_t^j$ and $\mathcal{D}_t^j/\mathcal{E}_t$ to be correlated with international variables conditional on macro shocks (e.g. to productivity, inflation, etc.). It is also worth emphasizing that sets $\mathcal{A}$ and $\mathcal{A}^*$ do not coincide respectively with J_t and J_t^* and generally do not cover all assets traded in the economy.

With this definition at hand, we can formalize the disconnect between exchange rates and financial variables as follows:

Definition 2 (Financial disconnect in the limit) *Denote with* $\mathbf{F}_t \equiv \{\Theta_t^i, \Theta_t^j/\mathcal{E}_t\}$*, where* $i \in \mathcal{A}$ *and* $j \in \mathcal{A}^*$*, a vector of asset prices that are not mechanically correlated with the exchange rate, and with* $\varepsilon_t \equiv \mathbf{V}'\Omega_t + \mathbf{V}^{*\prime}\Omega_t^*$ *an arbitrary combination of shocks* $\Omega_t = \{p_t, \kappa_t, a_t, g_t, \mu_t, \eta_t, \xi_t, \psi_t^j\}$.

We say that an open economy (with $\gamma > 0$) exhibits financial disconnect in the autarky limit if

$$\lim_{\gamma\to 0}\frac{\mathrm{d}\mathbf{F}_t}{\mathrm{d}\varepsilon_t} = 0 \qquad \textit{and} \qquad \lim_{\gamma\to 0}\frac{\mathrm{d}\mathcal{E}_t}{\mathrm{d}\varepsilon_t} \neq 0. \tag{20}$$

In words, the definition requires that when economy get arbitrary close to trade autarky, the candidate shocks still generate movements in exchange rates, but have vanishingly small effect on prices of assets that are not mechanically correlated with the exchange rate.[11] In addition to focusing on different empirical moments, the important difference between this definition and the definition of the macro disconnect above is that we now allow for incomplete markets and therefore, structural shocks can generate endogenous deviations from the Backus-Smith condition. For example, with one internationally traded bond, a news shock about future productivity generates an immediate jump in C_t/C_t^* and $\mathcal{Q}_t$ due to intertemporal consumption smoothing despite no changes in fundamentals in period t.

Proposition 3 *Suppose that the sets $\mathcal{A}$ and $\mathcal{A}^*$ are sufficiently rich. Then the model of Section 2 cannot exhibit financial disconnect in the autarky limit (20) if the combined shock ε_t in Definition 2 has a weight of zero on the subset of shocks $\{\eta_t, \eta_t^*, \xi_t, \xi_t^*, \psi_t^j, \psi_t^{*j}\}$.*

The intuition for this result can be clearly seen from the household Euler equations (5) and (11) rewriten as asset pricing equations:

$$\Theta_t^j = \mathbb{E}_t \sum\nolimits_{\tau=1}^{\infty} \mathcal{M}_{t,t+\tau}\mathcal{D}_{t+\tau}^j e^{-\Psi_{t,t+\tau}^j}, \tag{21}$$

$$\frac{\Theta_t^j}{\mathcal{E}_t} = \mathbb{E}_t \sum\nolimits_{\tau=1}^{\infty} \mathcal{M}_{t,t+\tau}^* \frac{\mathcal{D}_{t+\tau}^j}{\mathcal{E}_{t+\tau}} e^{-\Psi_{t,t+\tau}^{*j}}, \tag{22}$$

where $\mathcal{M}_{t,t+\tau} \equiv \beta^\tau \left(\frac{C_{t+\tau}}{C_t}\right)^{-\sigma} \frac{P_t}{P_{t+\tau}}$ and $\mathcal{M}_{t,t+\tau}^* \equiv \beta^\tau \left(\frac{C_{t+\tau}^*}{C_t^*}\right)^{-\sigma} \frac{P_t^*}{P_{t+\tau}^*}$ are home and foreign nominal stochastic discount factors (SDF) and $\Psi_{t,t+\tau}^j \equiv \sum_{i=1}^{\tau} \psi_{t+i}^j$ and $\Psi_{t,t+\tau}^{*j} \equiv \sum_{i=1}^{\tau} \psi_{t+i}^{*j}$ are the accumulated asset shocks. Because nominal SDFs $\mathcal{M}_{t,t+\tau}, \mathcal{M}_{t,t+\tau}^*$ depend on present and future macro shocks $\{\Omega_t^{\varnothing}\}$ via the path of consumption and inflation, such shocks cannot generate a disconnect between exchange rates and asset prices. The technical requirement that sets $\mathcal{A}, \mathcal{A}^*$ are sufficiently large ensures that one cannot find a linear combination of shocks that moves the exchange rate, but has perfectly offsetting effects on all asset prices.

This is a powerful result as it suggests that even very persistent or delayed macro shocks with the dominating news component about future realizations are an unlikely solution to the

[11] Because asset positions are rarely observable in practice, the definition of the disconnect focuses exclusively on asset prices and does not require that movements in exchange rates are not correlated with changes in portfolios.

disconnect puzzle if one brings in asset pricing moments.[12] The proposition also implies that news shocks about future terms of trade and foreign demand are not inconsistent with the financial disconnect — at least, unless one brings in the prices of exported and imported goods (commodities) and asset prices of exporters and importers as additional data.

Finally, we can use the same approach to go beyond macro shocks and verify which financial shocks can move exchange rates without affecting asset prices:

Proposition 4 *Shocks ψ_t^{*j}, $j \in \mathcal{A}$ and ψ_t^i, $i \in \mathcal{A}^*$ can generate financial disconnect in the autarky limit* (20).

The intuition can again be seen from equations (21)–(22). In the autarky limit, the SDF $\mathcal{M}_{t,t+\tau}$ is determined solely by local shocks. By definition, the same applies to dividends $\mathcal{D}_t^j$ of the assets from the set $\mathcal{A}$ and to dividends $\mathcal{D}_t^i/\mathcal{E}_t$ from the set $\mathcal{A}^*$. It follows that prices of assets in home currency Θ_t^j from set $\mathcal{A}$ are determined by domestic households and therefore, any foreign demand shocks for these assets ψ_t^{*j} have to be absorbed by movements in the exchange rate. A symmetric argument applies to assets from set $\mathcal{A}^*$ and home asset demand shocks ψ_t^i.

Notice that all other financial shocks will in general case affect both the exchange rate and asset prices. In particular, this applies to asset-specific shocks that are common to both economies $\psi_t^j = \psi_t^{*j}$, which directly change the asset price Θ_t^j, but might affect the exchange rates indirectly through valuation effects in the budget constraint. Similarly, country-specific asset demand shocks, $\psi_t^j = \psi_t$ for all $j \in J_t$, are isomorphic to a discount rate shock χ_t, and are absorbed by changes in domestic asset prices. A low correlation between exchange rates and short-term nominal interest rates supports the conclusion that such shocks cannot be the main drivers of exchange rates.

4 Conclusion

[12] Engel and West (2005) shows that the exchange rate follows a random walk when driven by integrated shocks of the form $\Delta x_t = \rho \Delta x_{t-1} + \varepsilon_t$. See also Corsetti, Dedola, and Leduc (2008) for the case of endogenous sluggish propagation of shocks due to capital accumulation.

A Appendix

A.1 Equilibrium system

We summarize here the equilibrium system of the general model from Section 2 by breaking it into blocks:

1. Labor supply (3) and its exact foreign counterpart.
2. Labor demand in (6), the definition of the marginal cost (7), and their exact foreign counterparts.
3. Goods market clearing and demand for home and foreign goods:

$$Y_t = Y_{Ht} + Y^*_{Ht} \qquad \text{and} \qquad Y^*_t = Y_{Ft} + Y^*_{Ft}, \tag{A1}$$

   where the sources of demand for home good are given in (13) and (14), and the counterpart sources of demand for foreign good are given by:

$$Y_{Ft} = \gamma e^{(1-\gamma)\xi_t} h\left(\frac{P_{Ft}}{P_t}\right)[C_t + G_t], \tag{A2}$$

$$Y^*_{Ft} = (1-\gamma)e^{-\gamma\xi^*_t} h\left(\frac{P^*_{Ft}}{P^*_t}\right)[C^*_t + G^*_t]. \tag{A3}$$

4. Supply of goods: given price setting (9) and its foreign counterpart given by:

$$P_{Ft} = e^{\mu^*_t + \eta^*_t} MC^*_t \mathcal{E}_t, \qquad P^*_{Ft} = e^{\mu^*_t} MC^*_t, \tag{A4}$$

   and associated CES price indexes for $P_t = e^{p_t}$ and $P^*_t = e^{p^*_t}$, which are chosen as local nominal numeraires, output produced is determined by the demand equation (A1).
5. Asset demand by home and foreign households (5) and (11).
6. Home-country flow budget constraint (16), with its foreign counterpart redundant by Walras Law.

A.1.1 Symmetric steady state

In a symmetric steady state, $B^j = B^{*j} = 0$ and the following shocks take zero values:

$$\psi^j = \psi^{*j} = \xi = \xi^* = \eta = \eta^* = 0,$$

and we normalize $p = p^* = 0$. We let the remaining shocks take arbitrary symmetric values:

$$a = a^*, \qquad g = g^*, \qquad \kappa = \kappa^* \qquad \text{and} \qquad \mu = \mu^*.$$

We start with the equations for prices. In a symmetric steady state, exchange rates and terms of trade are equal to 1:

$$\mathcal{E} = \mathcal{Q} = \mathcal{S} = 1, \tag{A5}$$

and therefore we can evaluate prices and wages using the equilibrium conditions described above:

$$P = P^* = P_H = P_F^* = P_H^* = P_F = 1 \qquad \text{and} \qquad W = W^* = e^{a-\mu}. \tag{A6}$$

Next we use these expressions together with production function, labor demand and labor supply to obtain two relationships for (C, Y, L):

$$L = e^{-a}Y, \qquad C^\sigma L^{1/\varphi} = e^{-\kappa}W = e^{a-\nu-\kappa}. \tag{A7}$$

Substitute prices into the goods market clearing to obtain an additional relationship between C and Y:

$$C + e^g = Y. \tag{A8}$$

Note that We further have $Y = Y^*$, and $Y_H = Y_F^* = (1-\gamma)Y$ and $Y_H^* = Y_F = \gamma Y$.

A.1.2 Log-linearized system

We log-linearize the equilibrium system around the symmetric steady state. We split the equilibrium system into three blocks — prices, quantities and dynamic equations.

Exchange rates and prices The price block contains the definitions of the price index and its foreign counterpart:

$$p_t = (1-\gamma)p_{Ht} + \gamma p_{Ft}^*, \tag{A9}$$

$$p_t^* = \gamma p_{Ht}^* + (1-\gamma)p_{Ft}^*, \tag{A10}$$

as well as the price setting equations (9) and (A4), in which we substitute the marginal cost (7) and its foreign counterpart, and log-linearize to obtain:

$$p_{Ht} = \mu_t - a_t + w_t, \tag{A11}$$
$$p^*_{Ht} = \mu_t + \eta_t - a_t + w_t - e_t, \tag{A12}$$
$$p^*_{Ft} = \mu^*_t - a^*_t + w^*_t, \tag{A13}$$
$$p_{Ft} = \mu^*_t + \eta^*_t - a^*_t + w^*_t + e_t. \tag{A14}$$

In addition, we use the logs of the definitions of the real exchange rate and terms of trade (17):

$$q_t = p^*_t + e_t - p_t, \tag{A15}$$
$$s_t = p_{Ft} - p^*_{Ht} - e_t. \tag{A16}$$

Combine (A15)–(A16) to obtain:

$$q_t = (1-\gamma)q^P_t - \gamma s_t, \tag{A17}$$
$$s_t = q^P_t - 2\tilde{\eta}_t, \tag{A18}$$

where $q^P_t = p^*_{Ft} + e_t - p_{Ht}$ is the producer-price-based real exchange rate and we use the tilde notation $\tilde{x}_t \equiv (x_t - x^*_t)/2$ for any pair of variables (x_t, x^*_t). Lastly, we solve for q^P_t and s_t as function of q_t:

$$q^P_t = \frac{1}{1-2\gamma}q_t - \frac{2\gamma}{1-2\gamma}\tilde{\eta}_t, \tag{A19}$$
$$s_t = \frac{1}{1-2\gamma}q_t - \frac{2(1-\gamma)}{1-2\gamma}\tilde{\eta}_t. \tag{A20}$$

Next, we use these solutions together with the expressions for price indexes (A9), to solve for:

$$p_{Ht} - p_t = -\frac{\gamma}{1-\gamma}(p_{Ft} - p_t) = \gamma(p_{Ht} - p_{Ft}) = -\frac{\gamma}{1-2\gamma}q_t + \frac{\gamma^2\eta_t - \gamma(1-\gamma)\eta^*_t}{1-2\gamma}, \tag{A21}$$
$$p^*_{Ft} - p^*_t = -\frac{\gamma}{1-\gamma}(p^*_{Ht} - p^*_t) = \gamma(p^*_{Ft} - p^*_{Ht}) = \frac{\gamma}{1-2\gamma}q_t + \frac{\gamma^2\eta^*_t - \gamma(1-\gamma)\eta_t}{1-2\gamma}. \tag{A22}$$

Combining these expression with (A11) and (A13), we can solve for wages:

$$w_t = -\mu_t + \frac{\gamma^2\eta_t - \gamma(1-\gamma)\eta^*_t}{1-2\gamma} + a_t - \frac{\gamma}{1-2\gamma}q_t, \tag{A23}$$
$$w^*_t = -\mu^*_t + \frac{\gamma^2\eta^*_t - \gamma(1-\gamma)\eta_t}{1-2\gamma} + a^*_t + \frac{\gamma}{1-2\gamma}q_t, \tag{A24}$$

which together allow to solve for the relationship between q_t and nominal exchange rate e_t:

$$\frac{1}{1-2\gamma}q_t = e_t - 2\tilde{w}_t + 2\tilde{a}_t - 2\tilde{\mu}_t + \frac{2\gamma}{1-2\gamma}\tilde{\eta}_t. \tag{A25}$$

Real exchange rate and quantities The supply side is the combination of labor supply (3) and labor demand (6), which we log-linearize as:

$$\kappa_t + \sigma c_t + \tfrac{1}{\varphi}\ell_t = w_t - p_t, \tag{A26}$$

$$\ell_t = y_t - a_t. \tag{A27}$$

Combining the two to solve out ℓ_t, and using (A23) to solve out $(w_t - p_t)$, we obtain:[13]

$$\varphi\sigma c_t + y_t = (1+\varphi)a_t - \varphi\left[\mu_t - \frac{\gamma^2\eta_t - \gamma(1-\gamma)\eta_t^*}{1-2\gamma} + \frac{\gamma}{1-2\gamma}q_t\right] - \varphi\kappa_t. \tag{A28}$$

Symmetrically, the same expression for foreign is:

$$\varphi\sigma c_t^* + y_t^* = (1+\varphi)a_t^* - \varphi\left[\mu_t^* - \frac{\gamma^2\eta_t^* - \gamma(1-\gamma)\eta_t}{1-2\gamma} - \frac{\gamma}{1-2\gamma}q_t\right] - \varphi\kappa_t^*.$$

Adding and subtracting the two we obtain:

$$\varphi\sigma\bar{c}_t + \bar{y}_t = (1+\varphi)\bar{a}_t - \varphi(\bar{\mu}_t + \gamma\bar{\eta}_t) - \varphi\bar{\kappa}_t, \tag{A29}$$

$$\varphi\sigma\tilde{c}_t + \tilde{y}_t = (1+\varphi)\tilde{a}_t - \varphi\left[\tilde{\mu}_t - \frac{\gamma}{1-2\gamma}\tilde{\eta}_t + \frac{\gamma}{1-2\gamma}q_t\right] - \varphi\tilde{\kappa}_t, \tag{A30}$$

where $\bar{x}_t \equiv (x_t + x_t^*)/2$ for any pair of variables (x_t, x_t^*).

The demand side is the goods market clearing (A1) together with (13)–(14), which we log-linearize as:

$$\begin{aligned} y_t &= (1-\gamma)y_{Ht} + \gamma y_{Ht}^*, \\ y_{Ht} &= -\gamma\xi_t - \theta(p_{Ht} - p_t) + \varsigma c_t + (1-\varsigma)g_t, \\ y_{Ht}^* &= (1-\gamma)\xi_t^* - \theta(p_{Ht}^* - p_t^*) + \varsigma c_t^* + (1-\varsigma)g_t^*, \end{aligned}$$

where $\varsigma \equiv C/(C+G)$. Combining together, we derive:

$$y_t - \varsigma[c_t - 2\gamma\tilde{c}_t] = \frac{2\gamma(1-\gamma)\theta}{1-2\gamma}q_t + (1-\varsigma)[g_t - 2\gamma\tilde{g}_t] + \frac{\gamma(1-\gamma)\theta}{1-2\gamma}(\eta_t + \eta_t^*) - 2\gamma(1-\gamma)\tilde{\xi}_t, \tag{A31}$$

where we have solved out $(w_t - p_t)$ and $(w_t^* - p_t^*)$ using (A23)–(A24) and solved out $(p_{Ht} - p_t)$

[13] A useful interim step is: $\varphi\sigma c_t + y_t = (\varphi + \phi)(w_t - p_t) + a_t - \varphi\kappa_t$.

and $(p^*_{Ht} - p^*_t)$ using (A21)–(A22). Adding and subtracting the foreign counterpart, we obtain:

$$\bar{y}_t = \varsigma \bar{c}_t + (1-\varsigma)\bar{g}_t + \frac{2\gamma(1-\gamma)\theta}{1-2\gamma}\bar{\eta}_t, \tag{A32}$$

$$\tilde{y}_t = (1-2\gamma)\Big[\varsigma \tilde{c}_t + (1-\varsigma)\tilde{g}_t\Big] - 2\gamma(1-\gamma)\tilde{\xi}_t + \gamma\frac{2(1-\gamma)\theta}{1-2\gamma}q_t. \tag{A33}$$

An immediate implication of (A29) and (A32) is that $(\bar{y}_t, \bar{c}_t)$ depends only on $(\bar{a}_t, \bar{g}_t, \bar{\kappa}_t, \bar{\mu}_t, \bar{\eta}_t)$ and does not depend on the real exchange rate q_t. In particular, if $\bar{a}_t = \bar{g}_t = \bar{\kappa}_t = \bar{\mu}_t = \bar{\eta}_t = 0$, then $\bar{y}_t = \bar{c}_t = 0$. This is the case we focus on throughout the paper, since as we see below the variation in $(\bar{a}_t, \bar{g}_t, \bar{\kappa}_t, \bar{\mu}_t, \bar{\eta}_t)$ does not affect q_t. Combining (A30) and (A33) we can solve for $\tilde{y}_t$ and $\tilde{c}_t$. For example, the expression for $\tilde{c}_t$ is:

$$\Big[(1-2\gamma)(\varphi\sigma+\varsigma) + 2\gamma\varphi\sigma\Big]\tilde{c}_t = (1+\varphi)\tilde{a}_t - \varphi\tilde{\mu}_t - \varphi\tilde{\kappa}_t - (1-2\gamma)(1-\varsigma)\tilde{g}_t \\ + \gamma\varphi\tilde{\eta}_t + 2\gamma(1-\gamma)\tilde{\xi}_t - \frac{\gamma}{1-2\gamma}\left[2(1-\gamma)\theta + \varphi\right]q_t. \tag{A34}$$

Lastly, we provide the linearized expression for net exports:

$$nx_t = \gamma\Big(y^*_{Ht} - y_{Ft} - s_t\Big),$$

where $nx_t = \frac{1}{P_H Y} NX_t$ is linear deviation of net exports from steady state $NX = 0$ relative to the total value of output. Substituting in the expressions for s_t, y^*_{Ht} and y_{Ft}, we obtain:

$$nx_t = \gamma\frac{2(1-\gamma)\theta - 1}{1-2\gamma}q_t - 2\gamma[\varsigma\tilde{c}_t + (1-\varsigma)\tilde{g}_t] - 2\gamma(1-\gamma)\tilde{\xi}_t - 2\gamma(1-\gamma)\left[\theta + \frac{1}{1-2\gamma}\right]\tilde{\eta}_t.$$

Exchange rate and asset prices It only remains now to log-linearize the asset demand conditions (5) and (11), which pins down the equilibrium asset prices, as well as provides an international risk sharing condition:

$$\mathbb{E}_t\left\{\sigma\Delta c_{t+1} + \Delta p_{t+1} - r^j_{t+1} + \psi^j_{t+1}\right\} = 0,$$
$$\mathbb{E}_t\left\{\sigma\Delta c^*_{t+1} + \Delta p^*_{t+1} - r^j_{t+1} + \Delta e_{t+1} - \psi^{*j}_{t+1}\right\} = 0,$$

where $r^j_{t+1} \equiv \log\frac{\Theta^j_{t+1} + \mathcal{D}_{t+1}}{\Theta^j_t}$. Combining the two, we obtain a risk-sharing (Backus-Smith) condition:

$$\mathbb{E}_t\left\{\sigma(\Delta c_{t+1} - \Delta c^*_{t+1}) - \Delta q_{t+1} + \psi^j_{t+1} - \psi^{*j}_{t+1}\right\} = 0. \tag{A35}$$

When the asset markets are complete, the international risk sharing (19) becomes

$$\Delta q_{t+1} = \sigma(\Delta c_{t+1} - \Delta c^*_{t+1}) + \Delta\zeta_t, \qquad \text{where} \quad \Delta\zeta_t \equiv \psi_t - \psi^*_t,$$

and, with some abuse of notation, ψ_t, ψ_t^* denote the state-by-state risk-sharing wedges.

A.2 Autarky Limit and Proofs for Section 3

Proof of Propositions 1 The strategy of the proof is to evaluate the log deviations of the macro variables $z_t \equiv (w_t, p_t, c_t, \ell_t, y_t)$ from the deterministic steady state (described in Appendix A.1.1) in response to a shock $\varepsilon_t = \mathbf{V}'\Omega_t \neq 0$.[14] In particular, we explore under which circumstances $\lim_{\gamma\to 0} z_t = 0$. It is sufficient to consider the log-linearized equilibrium conditions described in Appendix A.1.2, as providing a counterexample is sufficient for the prove (hence, the focus on the small log deviations is without loss of generality).

To prove the propositions, consider any shock ε_t with the restriction that

$$\eta_t = \eta_t^* = \xi_t = \xi_t^* = \psi_t \equiv 0. \tag{A36}$$

We now go through the list of requirements imposed by the first part of the condition (??):

1. No price response $\lim_{\gamma\to 0} p_t = 0$ implies $p_t = 0$, i.e. the monetary shocks cannot lead to the exchange rate disconnect in the limit. When the same requirements are imposed for foreign, it ensures $\lim_{\gamma\to 0}\{q_t - e_t\} = 0$, as immediartely follows from the the definition of the real exchange rate $q_t = p_t^* + e_t - p_t$ (see also (A25)).

2. No wage level response implies, using (A23) and (A36):

$$\lim_{\gamma\to 0} w_t = p_t - \mu_t + a_t = 0,$$

   which in light of $p_t = 0$ requires $\mu_t = a_t$, i.e. the markup shocks must offset the productivity shocks to avoid variation in the price level.

3. From the labor supply and labor demand conditions (A26)–(A27), no consumption, employment and output response require:

$$\lim_{\gamma\to 0}\left\{\sigma c_t + \tfrac{1}{\varphi}\ell_t\right\} = a_t - \mu_t - \kappa_t = 0,$$
$$\lim_{\gamma\to 0}\left\{y_t - \ell_t\right\} = a_t = 0,$$

   which then implies $a_t = \kappa_t \equiv 0$ and by consequence $\mu_t \equiv 0$ from the result above. That is, there cannot be productivity, markup or labor wedge shocks, if the wage level, consumption, output and employment are not to respond in the autarky limit.

[14] We do not impose any restrictions on the process for shocks in Ω_t, with the exception of the mild requirement that any innovation in Ω_t has some contemporaneous effect on the value of shocks in Ω_t, i.e. we rule out pure news shocks. We discuss examples with specific time series processes for the shocks in the end of this subsection.

4. Rearranging the goods market clearing in the home market (A31), we have:

$$\lim_{\gamma\to 0}\left\{y_t-\varsigma c_t\right\}=(1-\varsigma)g_t=0,$$

which requires $g_t\equiv 0$.

To summarize, the first condition in (18) (combined with the absence of η_t, ξ_t and ψ_t shocks) implies:

$$w_t=\chi_t=\kappa_t=a_t=\mu_t=g_t\equiv 0,$$

i.e. no other shock can be consistent with $\lim_{\gamma\to 0} z_t=0$. This leaves only news shocks about future values of these wedges. However, without risk-sharing wedges ($\tilde{\psi}_t=0$), the risk-sharing condition (19) implies

$$e_t=\sigma(c_t-c_t^*)+p_t-p_t^*,$$

Given that $p_t=p_t^*=0$ and $c_t-c_t^*=y_t-y_t^*$ in the autarky limit, the present exchange rate does not depend on future realizations of shocks and therefore, for any news shocks $\lim_{\gamma\to 0}e_t=0$, violating the second condition in (18). A symmetric argument for foreign rules out the foreign counterparts of these shocks. This completes the proof. ■

Proof of Proposition 2 For the proof, we consider the equilibrium system in the autarky limit by only keeping the lowest order terms in γ for each shock or variable.[15] Throughout the proof we impose $w_t=\chi_t=\kappa_t=a_t=\mu_t=g_t\equiv 0$, as well as for their foreign counterparts.

First, we consider our three moments of interest when $\tilde{\psi}_t$ is the only shock, that is we set $\eta_t=\xi_t\equiv 0$. For this purpose, it is sufficient to consider the static equilibrium conditions only, as the effect of the $\tilde{\psi}_t$ shock on the macro variables is exclusively indirect through q_t. Specifically:

1. Consider the near-autarky comovement between the terms of trade and the real exchange rate from (A20):

$$\lim_{\gamma\to 0}\frac{\operatorname{cov}(\Delta s_t,\Delta q_t)}{\operatorname{var}(\Delta q_t)}=1>0,$$

since we have $\tilde{\eta}_t=0$.

2. Consider the near-autarky comovement between the relative consumption and the real

[15] For example, consider equation (A25), which we now rewrite as:

$$q_t-e_t=2\big(\tilde{a}_t-\tilde{\mu}_t-\tilde{w}_t\big)+2\gamma\tilde{\eta}_t.$$

Note that the gap between q_t and e_t is zero-order in γ for shocks $(\tilde{a}_t,\tilde{\mu}_t,\tilde{w}_t)$ and first-order in γ for shock $\tilde{\eta}_t$.

exchange rate from (A34), which in the absence of all shocks but ψ_t simplifies to:

$$\Big[(1-2\gamma)(\varphi\sigma+\varsigma)+2\gamma\varphi\sigma\Big]\tilde{c}_t=-\gamma\left[\frac{2(1-\gamma)\theta}{1-2\gamma}+\frac{\varphi}{1-2\gamma}\right]q_t.$$

Hence, we have:

$$\lim_{\gamma\to 0}\frac{1}{\gamma}\frac{\operatorname{cov}\left(\Delta c_t-\Delta c_t^*,\Delta q_t\right)}{\operatorname{var}(\Delta q_t)}=-\frac{2\left(2\theta+\varphi\right)}{\varphi\sigma+\varsigma}<0,$$

which is negative for all parameter values.

3. Consider the near-autarky comovement between the nominal exchange rate and the nominal interest rate differential (the Fama coefficient), which we write in the limit as:

$$i_t-i_t^*=\mathbb{E}_t\{2\sigma\Delta\tilde{c}_{t+1}+2\Delta\tilde{p}_{t+1}\}=-\frac{2\gamma\sigma(2\theta+\varphi)}{\varphi\sigma+\varsigma}\mathbb{E}_t\Delta q_{t+1}.$$

where we used expression (A34) for $\tilde{c}_t$ and $p_t=p_t^*=0$. The latter condition also implies that $e_t=q_t$. Therefore, the Fama regression coefficient in the limit is:[16]

$$\lim_{\gamma\to 0}\gamma\frac{\operatorname{cov}\left(\mathbb{E}_t\Delta e_{t+1},i_t-i_t^*\right)}{\operatorname{var}\left(i_t-i_t^*\right)}=-\frac{2\gamma\sigma(2\theta+\varphi)}{\varphi\sigma+\varsigma}<0.$$

This proves the first claim of the proposition that the shock $\tilde{\psi}_t$ robustly and simultaneously produces the correct empirical signs for all three moments in the autarky limit.

It is also easy to check directly from the risk sharing condition (19) that the dispersion of the real and nominal (by corollary of Definition 1) exchange rates is separated from zero in response to these shocks.

Second, the uncovered interest rate parity implies that the Fama regression coefficient:

$$\beta_F\equiv\frac{\operatorname{cov}(\Delta e_{t+1},i_t-i_t^*)}{\operatorname{var}(i_t-i_t^*)}=1\qquad\text{whenever}\qquad\tilde{\psi}_t\equiv 0.$$

This follows from the linearized Euler equations (5) and (11) for one-period risk-free nominal bonds with price Θ_t^f and Θ_t^{*f} and payoffs $\mathcal{D}_{t+1}^f=1$ and $\mathcal{D}_{t+1}^{*f}=\mathcal{E}_{t+1}$:

$$\begin{aligned}i_t&=\log(\beta/\Theta_t^f)=\mathbb{E}_t\{\sigma\Delta c_{t+1}+\Delta p_{t+1}+\psi_{t+1}^f\},\\ i_t^*&=\log(\beta\mathcal{E}_t/\Theta_t^{*f})=\mathbb{E}_t\{\sigma\Delta c_{t+1}^*+\Delta p_{t+1}^*+\psi_{t+1}^{*f}\},\end{aligned}$$

[16] We make use of the fact that $\operatorname{cov}\left(\Delta e_{t+1},i_t-i_t^*\right)=\operatorname{cov}\left(\mathbb{E}_t\Delta e_{t+1},i_t-i_t^*\right)$ since $i_t-i_t^*$ is in the period t information set.

and therefore

$$i_t - i_t^* = \mathbb{E}_t\{\sigma(\Delta c_{t+1} - \Delta c_{t+1}^*) + (\Delta p_{t+1} - \Delta p_{t+1}^*) + \tilde{\psi}_{t+1}^f\} = \mathbb{E}_t \Delta e_{t+1},$$

where we used $\tilde{\psi}_{t+1}^f = \psi_{t+1}^f - \psi_{t+1}^{*f} = 0$ and the risk-sharing condition (19) that implies $\sigma(\Delta c_{t+1} - \Delta c_{t+1}^*) + (\Delta p_{t+1} - \Delta p_{t+1}^*) = \Delta e_{t+1}$ given that $\Delta q_{t+1} = \Delta e_{t+1} - (\Delta p_{t+1} - \Delta p_{t+1}^*)$ and $\Delta \zeta_{t+1} = \tilde{\psi}_{t+1} = 0$. This implies the Fama coefficient of 1. Therefore, $(\eta_t, \eta_t^*, \xi_t, \xi_t^*)$ shocks that follow any joint process cannot resolve the forward premium puzzle.

Third, focus on the ξ_t and η_t shocks (setting all other shocks including $\tilde{\psi}_t$ to zero) and combine the goods market clearing condition (A34) with the risk sharing condition (19) to get

$$q_t = \frac{2\gamma\varphi\sigma}{\varphi\sigma + \varsigma}\tilde{\eta}_t + \frac{4\gamma\sigma}{\varphi\sigma + \varsigma}\tilde{\xi}_t,$$

where again we only keep lower-order terms in γ. From equation (A20), it follows then

$$s_t = -2\left[1 + \frac{\gamma\varsigma}{\varphi\sigma + \varsigma}\right]\tilde{\eta}_t + \frac{4\gamma\sigma}{\varphi\sigma + \varsigma}\tilde{\xi}_t.$$

Combining the last two equations, we get that $\lim_{\gamma\to 0}\frac{\text{cov}(\Delta s_t, \Delta q_t)}{\text{var}(\Delta q_t)} < 0$ for shocks $\tilde{\eta}_t$, i.e. law-of-one-price shocks generate a counterfactual negative correlation between the terms of trade and the real exchange rate (akin to the property of an LCP model, see Obstfeld and Rogoff 2000). At the same time, the international good demand shocks generate a positive correlation, i.e. $\lim_{\gamma\to 0}\frac{\text{cov}(\Delta s_t, \Delta q_t)}{\text{var}(\Delta q_t)} > 0$ for shocks $\tilde{\xi}_t$. Finally, the risk sharing condition $q_t = \sigma(c_t - c_t^*)$ implies that neither of the two shocks can deliver an empirically relevant negative correlation between the real exchange rate and the relative consumption. ■

Proof of Proposition 3 Shut down shocks to $\{\eta_t, \eta_t^*, \xi_t, \xi_t^*, \psi_t^j, \psi_t^{*j}\}$ and rewrite the asset pricing equations (21):

$$\Theta_t^j = \mathbb{E}_t\left\{\sum_{\tau=1}^{\infty}\beta^\tau\left(\frac{C_{t+\tau}}{C_t}\right)^{-\sigma}\frac{P_t}{P_{t+\tau}}\mathcal{D}_{t+\tau}^j\right\}, \qquad \frac{\Theta_t^j}{\mathcal{E}_t} = \mathbb{E}_t\left\{\sum_{\tau=1}^{\infty}\beta^\tau\left(\frac{C_{t+\tau}^*}{C_t^*}\right)^{-\sigma}\frac{P_t^*}{P_{t+\tau}^*}\frac{\mathcal{D}_{t+\tau}^j}{\mathcal{E}_{t+\tau}}\right\}.$$

Focusing on assets with payoffs independent of international variables $j \in \mathcal{A} \cup \mathcal{A}^*$ and trade autarky $\gamma \to 0$, it follows that the present and future monetary shocks $\{p_t\}$ have direct effect on asset prices via the nominal SDF. Similarly, the equilibrium conditions summarized in (A34) imply that the expectations about other macro shocks $\{\kappa_t, a_t, g_t, \mu_t\}$ determine the equilibrium path of $\{C_t\}$ and therefore, also affect asset prices via SDF. A symmetric argument applies to foreign shocks and foreign asset prices. The financial disconnect between exchange rates and asset prices is only possible if one combines these shocks in such a way that they only move

$\mathcal{E}_t$, but leave all Θ_t^j unchanged. This is generically impossible if the number of assets with imperfectly aligned payoffs is sufficiently large. ■

Proof of Proposition 4 Consider an asset $j \in \mathcal{A}$ with payoffs in home currency $\mathcal{D}_t^j$ independent of international variables. According to equation (21), the price of this asset in home currency is given by

$$\Theta_t^j = \mathbb{E}_t \left\{ \sum_{\tau=1}^{\infty} \mathcal{M}_{t,t+\tau} \mathcal{D}_{t+\tau}^j e^{-\Psi_{t,t+\tau}^j} \right\}.$$

In the autarky limit, the nominal SDF $\mathcal{M}_{t,t+\tau}$ is determined solely by local shocks $\{p_t, \kappa_t, a_t, g_t, \mu_t\}$ and does not depend directly or via endogenous variables on financial shocks $\{\psi_t^j, \psi_t^{*j}\}$. It follows that Θ_t^j is independent of foreign financial shocks ψ_t^{*j}. At the same time, the Euler equation for foreign households investing in the same asset implies

$$\frac{\Theta_t^j}{\mathcal{E}_t} = \mathbb{E}_t \left\{ \sum_{\tau=1}^{\infty} \mathcal{M}_{t,t+\tau}^* \frac{\mathcal{D}_{t+\tau}^j}{\mathcal{E}_{t+\tau}} e^{-\Psi_{t,t+\tau}^{*j}} \right\},$$

where SDF $\mathcal{M}_{t,t+\tau}^*$ is also independent of financial shocks. Thus, without changes in Θ_t^j, $\mathcal{M}_{t,t+\tau}^*$ or $\mathcal{D}_t^j$, the foreign demand shocks ψ_t^{*j} have to be absorbed by either current or future movements in nominal exchange rates $\{\mathcal{E}_t\}$. Therefore, these shocks create a disconnect between asset prices and exchange rates. A symmetric argument applies to assets $j \in \mathcal{A}^*$ and shocks ψ_t^j. ■

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