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Keywords

Capital mobility, Imperfect information, Inattentive consumers, Permanent income hypothesis

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Current Account Dynamics under Information Rigidity and Imperfect Capital Mobility*

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1 Introduction

During the first decade of this century, we observed that the United States and some countries in the euro area ran large current account deficits while China, Germany and the oil-producing countries ran large current account surpluses, resulting in the so-called global imbalances phenomenon. Since the presence of huge US current account deficits may lead in the future to costly rearrangements of the world economy, many researchers have intensively examined the sustainability of the US current account deficits, both from economic and policy perspectives. See, for example, Mann (2002), Summers (2004), Edwards (2005), Roubini, and Setser (2005), Eichengreen (2006), Rogoff (2006), Obstfeld and Rogoff (2007), and Feldstein (2008).[1] Recent studies further investigate the current account sustainability issue from wider perspectives. Aizenman and Sun (2010) examine the relationship between the duration of a country's current account deficit and its relative GDP size and find that, except for the US, they are negatively correlated. Gnimassoun and Mignon (2016) clarify the interactions among current account imbalances, output gaps, and exchange rate misalignments. Cavallo, Eichengreen, and Panizza (2018) focus on the episodes of large and persistent deficits and show that financing investment by foreign funding is risky and likely to end up with drops in investment and growth.

Despite a large number of studies on the current account sustainability issue, the standard intertemporal current account (ICA) model has not been very successful in accounting for its characteristics.[2] The observed data on the net output growth suggest that the ICA model with rational expectations (RE) underpredicts the persistence and volatility of the current account in OECD countries.[3] One of the reasons is that the predictions of the current account depend on consumption dynamics under the permanent income hypothesis. Under this hypothesis, changes in consumption have no serial correlation, but the observed changes in consumption are often persistent.[4] Such persistent changes in consumption have often been explained by hand-to-mouth consumers who have no access to financial markets (e.g., Campbell and Mankiw 1989, 1990).[5] In the context of the ICA model, the presence of hand-to-mouth consumers also means that the international capital mobility is imperfect.

[1] Obstfeld and Rogoff (2010) point out that the US accommodative stance monetary policy combined with low global interest rates played a key role in the global imbalances.

[2] See Nason and Rogers (2006) and the reference therein.

[3] Net output in the ICA model is obtained by subtracting investment and government spending from output. For a more formal definition, see Section 2.

[4] Carroll, Slacalek, and Sommer (2011) provide robust evidence on the persistence of consumption growth.

[5] For the international evidence on hand-to-mouth consumers, see Campbell and Mankiw (1991). The theoretical implications for hand-to-mouth consumers have been explored well in the general equilibrium models (e.g., Galí, López-Salido and Vallés 2004, 2007 and Bilbiie 2008).

Shibata and Shintani (1998) study the ICA model with such imperfect international capital mobility. They estimate the degree of imperfect capital mobility that can be translated into the fraction of hand-to-mouth consumers in the economy. This hybrid RE model, which combines forward-looking consumers and hand-to-mouth consumers, can well explain consumption dynamics but undermines the predicted volatility of the current account.

The objective of this paper is to modify the ICA model by generalizing the model with sticky information (SI). To better explain current account dynamics, we replace RE in the ICA model with SI as developed by Mankiw and Reis (2002, 2007) and Reis (2006). In the literature on the permanent income hypothesis, a number of previous studies have argued for the role of inattentiveness to shocks (e.g., Pischke 1995, Sims 2003, Reis 2006, Luo 2008, Sims 2010, Luo, Nie, and Young 2015, and Gabaix 2016, Carroll, Crawley, Slacalek, Tokuoka, and White 2018 among others). In these previous studies, agents are subject to information rigidities and inattentive to income shocks. The resulting consumption does not follow a random walk and the changes in consumption are persistent, depending on the degree of information rigidity. Overall, consumption dynamics with information rigidities are shown to fit the data of aggregate consumption well, unlike the RE model.

Following this line of research, we explore the current account dynamics under the SI model, one of the simplest models of information rigidity. Under SI, consumers cannot update their information with a constant probability. Consequently, some consumers are inattentive to news and such inattentive consumers stick to the consumption level planned in the past period. We demonstrate that the SI model can explain a persistent and volatile current account. The SI model is also good at predicting the volatility of changes in consumption. However, the SI model tends to overpredict the persistence of changes in consumption. To overcome this difficulty, we further investigate the hybrid SI model that combines forward-looking consumers with SI and hand-to-mouth consumers. Our finding is that, if we allow for a high degree of imperfect information and imperfect capital mobility, the hybrid SI model can account for both the current account and consumption. We obtained these findings using the Bayesian minimum distance estimator.

At least two important recent studies on open macroeconomy are closely related to our work in terms of the importance of information rigidity.[6] The first is Luo, Nie, and Young (2012) who extend the ICA model with rational inattention and robustness.[7] While our

[6] We also note that, apart from information rigidity, a number of the previous studies have investigated explanations for current account dynamics and are thus closely related to our paper. Examples include Glick and Rogoff (1995), Ghosh and Ostry (1997), Bergin and Sheffrin (2000), Işcan (2002), Gruber (2004), Kunieda and Shibata (2005), Kano (2008, 2009), and Kunieda, Okada, and Shibata (2016).

[7] See also a recent work by Li, Luo, and Nie (2017) who use rational inattention in studying international consumption comovement puzzle.

paper is similar to theirs in that economic agents in our model imperfectly observe state variables, the primary focus of Luo, Nie, and Young (2012) is on how robustness, that is, the uncertainty on the model economy, improves the ICA model's prediction and its interaction with rational inattention.[8] The other important contribution is Ekinci (2017) who develops the general equilibrium model under SI. His analysis of SI is motivated by explaining the well-known puzzles in the two-country, open-economy models, such as the real exchange rate volatility puzzle and the Backus-Smith puzzle. In contrast, our analysis of SI aims to understand the persistence and volatility of the current account in small open-economy models.[9]

This paper is organized as follows. In Section 2, we provide the evidence on current account dynamics. In Section 3, we present the RE and hybrid RE models and discuss the difficulty in reconciling the data. In Section 4, we describe the SI and hybrid SI models. Section 5 assesses their empirical performance. Section 6 concludes our analysis.

2 Evidence

The data source we use is the annual data from 16 OECD countries over 1980–2013 from the *International Financial Statistics Yearbook 2015* (IFS 2015) of the International Monetary Fund. Our list of the countries generally overlaps with those in the previous empirical studies such as Sheffrin and Woo (1990), Ghosh (1995), and Shibata and Shintani (1998), among others. The selected countries include Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Iceland, Italy, Japan, the Netherlands, Norway, Sweden, the UK, and the US. Here, current account data are constructed from the gross national income (GNI) minus the sum of the household final consumption expenditure, the gross capital formation, and the government final consumption expenditure.[10] The net output is defined by the gross

[8] Luo, Nie, and Young (2012) argue that the current account detrended by the Hodrick-Prescott (HP) filter tends to be *less* persistent than the standard RE model predicts. By contrast, we argue that the current account scaled by the net output tends to be *more* persistent than the standard RE model implies. The difference comes from the fact that Luo, Nie, and Young (2012) focus on the case where the detrended net output follows a stationary AR(1) process (as well as a random walk). Instead, we consider the case where the net output growth follows the AR(1) process, so that the first differenced net output (in log) is stationary as in many previous studies in the literature. For example, see Sheffrin and Woo (1990), Otto (1992), Ghosh (1995), Ghosh and Ostry (1997), Bergin and Sheffrin (2000), and Gruber (2004).

[9] See also Crucini, Shintani, and Tsuruga (2010), who assume SI and sticky prices in firms' price setting and explain the persistence and volatility of good-level real exchange rates.

[10] The data of GNI are not fully available for Germany and the Netherlands. In particular, the IFS 2015 does not report the nominal GNI in 2013 for Germany. For the sake of the comparison with other countries, we extrapolated the 2013 data of the nominal GNI using the growth rate from 2012 to 2013 of the nominal GNI reported in the 2017 year version of the IFS. For the Netherlands, the data of the nominal GNI are

domestic product (GDP) minus the sum of the gross capital formation and the government final consumption expenditure. Consumption is the household final consumption expenditure, including non-profit institutions serving households. All the series are converted to real series with the GDP deflator and measured in per capita terms.[11]

In our empirical analysis, the current account is normalized by the net output. This normalization is useful in describing the current account dynamics, particularly when the growth rate of the net output is stationary. A similar normalization was first employed by Campbell and Deaton (1989) in the context of the optimal saving rate under the permanent income hypothesis when labor income growth is stationary. For the same reason, we also express changes in consumption as a fraction of lagged net output. The same reformulation of consumption change has also been used by Shibata and Shintani (1998) in their analysis of the ICA model with imperfect capital mobility.

Table 1 assesses current account dynamics in the sample countries, as well as the net output growth and consumption. In the first two rows of the table, we report the cross-country average of the persistence and volatility of the current account. The persistence and volatility of the current account are denoted by ρ_{ca}^{data} and V_{ca}^{data}, respectively. The persistence is measured by the first-order autocorrelation and volatility is measured by the standard deviation ratio of the current account to net output growth.[12] In the volatility measure, when the current account is more volatile than the net output growth, V_{ca}^{data} exceeds one. The third row of the table shows the persistence of the net output growth, which is denoted by ϕ^{data}. Finally, we define the persistence and volatility of changes in consumption by $\rho_{\Delta c}^{data}$ and $V_{\Delta c}^{data}$, similar to ρ_{ca}^{data} and V_{ca}^{data}. For example, $V_{\Delta c}^{data}$ is measured by the standard deviation ratio of changes in consumption to the net output growth. They are reported in the last two rows of the table.

Table 1 indicates that the current account is much more persistent and volatile than the net output growth. We see that the observed persistence of the current account (ρ_{ca}^{data}) is 0.82, which is much more persistent than that of the net output growth of 0.16 (ϕ^{data}). While the table reports, for brevity, only the persistence averaged across countries, these inequalities

not available over 1980—2013. For this reason, we take current account data based on Balance of Payments Manual Fifth edition (BPM5) from the OECD website. To be consistent with the data source, the data from the OECD website are also used for constructing the net output for the Netherlands.

[11] If we use quarterly data, the net output and the current account constructed from the seasonally-adjusted series of the GDP, consumption, investment, and the government expenditure do not match the seasonally-adjusted series of net output and the current account. However, raw data (before the seasonal adjustment) are not typically available so that the seasonally adjusted series of net output and the current account cannot be constructed for many countries. For this reason, we use annual data in our analysis.

[12] The first-order autocorrelation can be consistently estimated by the OLS estimator of the autoregressive coefficient in an AR(1) model.

are preserved for all single-country data. When we examine the volatility (V_{ca}^{data}), the current account is about twice as volatile as the net output growth. In terms of the single-country data, the volatility of the current account in all countries except for Japan exceeds unity. We note that the persistence of changes in consumption ($\rho_{\Delta c}^{data}$) deviates from zero, and is 0.25 on average. The volatility of changes in consumption ($V_{\Delta c}^{data}$) is about unity on average. This result implies that changes in consumption are as volatile as the net output growth.

3 The RE models

In this section, we present RE models, focusing on the persistence and volatility of the current account.

3.1 Setup

Consider a small open economy inhabited by a continuum of identical consumers located in a unit interval. A consumer's lifetime expected utility is $\mathbb{E}_t \sum_{j=0}^{\infty} \beta^j u\left(C_{t+j}\right)$ where C_t denotes consumption and β is the discount factor satisfying $\beta \in (0,1)$. Also, $\mathbb{E}_t[\cdot]$ represents the expectations operator, conditional on the information available in period t. Following Uribe and Schmitt-Grohé (2017), we specify $u(\cdot)$ as $u(C_t) = -0.5\left(C_t - \bar{C}\right)^2$, where $\bar{C}$ is the bliss point so that $C_t < \bar{C}$ for all t. The consumers' flow budget constraint is

$$A_{t+j+1} = (1+r)A_{t+j} + X_{t+j} - C_{t+j}, \tag{1}$$

for all $j \geq 0$. Here, A_t denotes foreign asset holdings at the beginning of period t. In this budget constraint, consumers have access to perfect international capital markets where capital can be saved or borrowed at a constant world interest rate r. To facilitate the analysis, we assume that the rate of time preference is equal to r: $\beta = 1/(1+r)$. Finally, X_t is the exogenous stochastic endowment, which we can also interpret as the net output.

The first-order condition implies that $C_t = \mathbb{E}_t C_{t+j}$ for $j = 1, 2, ...$ The optimal consumption is given by

$$C_t = rA_t + X_t^p, \tag{2}$$

where X_t^p is the non-financial permanent income given by $X_t^p = [r/(1+r)] \sum_{j=0}^{\infty} (1+r)^{-j} \mathbb{E}_t X_{t+j}$. Changes in consumption are calculated as $\Delta C_{t+1} = \Delta \mathbb{E}_{t+1} X_{t+1}^p$, where $\Delta \mathbb{E}_{t+1}$ denotes a change in the expectations operator defined by $\Delta \mathbb{E}_{t+1} = \mathbb{E}_{t+1} - \mathbb{E}_t$. This equation means that consumption between periods t and $t+1$ changes only if changes in the permanent income are recognized by consumers.

By the fundamental balance-of-payments identity, the current account CA_t equals changes in the country's net foreign assets (i.e., $CA_t \equiv A_{t+1} - A_t$). Therefore, using (1) and (2), we have

$$CA_t = X_t - X_t^p = -\sum_{j=1}^{\infty} (1+r)^{-j} \mathbb{E}_t \Delta X_{t+j}, \tag{3}$$

meaning that the current account is minus the present discounted value of future expected changes in the net output.

It is straightforward to extend this standard RE model with imperfect capital mobility. Shibata and Shintani (1998) consider consumers without access to the international capital market, as in Campbell and Mankiw (1989, 1990). A fraction $\lambda \in [0, 1)$ of consumers hold neither international financial assets nor liabilities: They are hand-to-mouth consumers who consume all endowment within a single period. The remaining fraction $1 - \lambda$ of consumers have full access to international capital markets and their consumption is determined by (2). We call this model the *hybrid* RE model. Denoting the aggregate consumption in the hybrid model by C_t^{HY}, we express $C_t^{HY} = (1 - \lambda) C_t + \lambda X_t$. Likewise, let CA_t^{HY} be the current account in the hybrid model. Because hand-to-mouth consumers do not hold international financial assets, CA_t^{HY} becomes

$$CA_t^{HY} = (1 - \lambda) CA_t. \tag{4}$$

This result implies that the magnitude of the current account becomes smaller than the case of perfect capital mobility described by (3). We thus call λ the degree of imperfect capital mobility.

3.2 Characterizing the RE models

We characterize the RE models's predictions under the assumption that the net output growth follows the AR(1) process. Let $g_{Xt} \equiv \ln(X_t/X_{t-1})$ be the net output growth. Assume that $g_{Xt} = (1 - \phi) \mu + \phi g_{Xt-1} + \varepsilon_t$, where $\varepsilon_t \sim i.i.d. (0, \sigma^2)$ and $|\phi| < 1$. As discussed in Campbell and Deaton (1989), this assumption of the stationary net output growth rate requires some reformulation of the variables. In particular, to ensure the stationarity of the current account, we divide both sides of (3) by X_t. We obtain $ca_t \equiv CA_t/X_t = -\sum_{j=1}^{\infty} (1+r)^{-j} \mathbb{E}_t (\Delta X_{t+j}/X_t)$. While we will elaborate on the model with $\mu \neq 0$ in Section 5, we temporarily set $\mu = 0$ for expositional purposes only. In this case, the first-order approximation of ca_t yields

$$ca_t \simeq -\sum_{j=1}^{\infty} (1+r)^{-j} \mathbb{E}_t g_{Xt+j} = -\frac{\phi}{1+r-\phi} g_{Xt}. \tag{5}$$

Throughout the paper, we focus on comparisons of the persistence and volatility of the current account across the models and the data. To facilitate the comparisons, we use a superscript that represents the model in expressing the persistence and volatility. In particular, we define ρ_{ca}^{RE} as the first-order autocorrelation of ca_t predicted by the pure RE model. If the model is the hybrid RE model, the corresponding persistence is $\rho_{ca}^{HY\text{-}RE}$. The same rule applies to the notation of volatility measures: V_{ca}^{RE} and $V_{ca}^{HY\text{-}RE}$. They are defined by the predicted standard deviation ratio of the current account to net output growth. We also use similar notations for changes in consumption (e.g., $\rho_{\Delta c}^{RE}$ and $V_{\Delta c}^{RE}$) and for the pure SI and hybrid SI models in the subsequent sections (i.e., ρ_{ca}^{SI} and V_{ca}^{SI} for the pure SI model and $\rho_{ca}^{HY\text{-}SI}$ and $V_{ca}^{HY\text{-}SI}$ for the hybrid SI model).

The left column of Table 2 characterizes the predictions of the (pure) RE model. The proportionality of ca_t to g_{Xt} in (5) implies that the persistence of ca_t should be the same as that of g_{Xt}, namely, $\rho_{ca}^{RE} = \phi$. It also implies that the predicted volatility is given by $V_{ca}^{RE} = |\phi| / (1+r-\phi)$. Changes in consumption are serially uncorrelated in the RE model, due to Hall's random walk hypothesis. In our case, with the reformulation of variables, we define $\Delta c_{t+1} \equiv \Delta C_{t+1}/X_t$. The solution for this normalized variable is expressed as $\Delta c_{t+1} = \Delta \mathbb{E}_{t+1} \left(X_{t+1}^p / X_t \right) \simeq [(1+r) / (1+r-\phi)] \, \varepsilon_{t+1}$, using the first-order approximation. Since ε_t is independent and identically distributed, the predicted persistence of changes in consumption is zero, namely, $\rho_{\Delta c}^{RE} = 0$. As we note that g_{Xt} follows the AR(1) process and $sd\,(g_{Xt}) = \sigma / \sqrt{1-\phi^2}$, the predicted volatility for changes in consumption is given by $V_{\Delta c}^{RE} = sd\,(\Delta c_t) / sd\,(g_{Xt}) = [(1+r) / (1+r-\phi)] \sqrt{1-\phi^2}$.

These predictions of the RE model are inconsistent with the evidence presented in Section 2. The RE model underpredicts the persistence of the current account. While the model predicts that $\rho_{ca}^{RE} = \phi$, the data suggest that $\rho_{ca}^{data} > \phi^{data}$ (See Table 1). It also underpredicts the volatility of the current account. In particular, when $r = 0.04$ and $\phi = 0.16$, the formula in Table 2 implies that $V_{ca}^{RE} = 0.18$, which is much lower than $V_{ca}^{data} \simeq 2$. For the RE model to generate $V_{ca}^{RE} \simeq 2$, ϕ needs to be as large as 0.69, as opposed to the data of $\phi^{data} = 0.16$.[13] As we turn to consumption dynamics, the RE model underpredicts the persistence of changes in consumption. While the data suggest that $\rho_{\Delta c}^{data} > 0$, the RE model implies that $\rho_{\Delta c}^{RE} = 0$. As for the volatility, it is slightly overpredicted ($V_{\Delta c}^{RE} = 1.17$ when $r = 0.04$ and $\phi = 0.16$,

[13] Solving $V_{ca}^{RE} \simeq 2 = \phi / (1+r-\phi)$ for ϕ yields $\phi \simeq 2\,(1+r)/3$. When $r = 0.04$, ϕ turns to be 0.69.

as opposed to $V_{\Delta c}^{data} = 1.02$).

The hybrid RE model of Shibata and Shintani (1998) can generate better predictions for changes in consumption. Again, denoting $\Delta c_{t+1}^{HY} \equiv \Delta C_{t+1}^{HY}/X_t$, we have $\Delta c_{t+1}^{HY} \simeq (1-\lambda)\,\Delta c_{t+1} + \lambda g_{Xt+1}$ in the hybrid RE model. As indicated in the right column of Table 2, the predicted persistence is given by $\rho_{\Delta c}^{HY\text{-}RE} = \Lambda\phi \neq 0$, where $\Lambda \in [0,1]$ is a function of λ and the second moments of Δc_t and g_{Xt}.[14] This outcome means that imperfect capital mobility can increase the persistence of changes in consumption as long as $\phi > 0$. Moreover, this friction tends to decrease the volatility of changes in consumption in the hybrid RE model. For example, when $\lambda = 0.5$, $V_{\Delta c}^{HY\text{-}RE} = 1.08$ so that the volatility of changes in consumption is closer to the volatility of 1.02 in the data. In an extreme case of $\lambda \to 1$, $V_{\Delta c}^{HY}$ approaches to unity, based on the formula provided in Table 2.

However, the better predictions for changes in consumption are achieved at the cost of undermining its predicted volatility of the current account. Because $CA_t^{HY} = (1-\lambda)\,CA_t$ from (4), $ca_t^{HY} = (1-\lambda)\,ca_t = -(1-\lambda)\,\phi/\,(1+r-\phi)\,g_{Xt}$, where $ca_t^{HY} \equiv CA_t^{HY}/X_t$. The proportionality of ca_t^{HY} to ca_t means that the first-order autocorrelation of ca_t^{HY} is unchanged in comparison to the pure RE model: $\rho_{ca}^{HY\text{-}RE} = \rho_{ca}^{RE} = \phi$. This proportionality also implies that $V_{ca}^{HY\text{-}RE} = (1-\lambda)\,V_{ca}^{RE}$. Therefore, as long as $\lambda > 0$, the problem of underpredicted volatility becomes more severe in the hybrid RE model than in the pure RE model. As a result, for the hybrid RE model to generate $V_{ca}^{HY\text{-}RE} \simeq 2$, the hybrid model needs an even larger value of ϕ than the pure RE model does. For example, if $r = 0.04$ and $\lambda = 0.50$, the hybrid RE model requires that $\phi = 0.83$, which is larger than 0.69 required in the pure RE model.[15]

4 The SI models

To improve predictions of the ICA model, we replace RE in the ICA model with SI. In this section, we leave the detailed maximization problem of the SI model to Appendix A.1 and focus on predictions of the SI model.

[14] The explicit form of Λ is provided by (24) in Section 4.

[15] Our choice of λ roughly matches the cross-country average of the estimates in Shibata and Shintani (1998). To obtain $\phi \simeq 0.83$, we solve $V_{ca}^{HY\text{-}RE} \simeq 2 = (1-\lambda)\,\phi/\,(1+r-\phi)$ for ϕ. The solution is $\phi = 2\,(1+r)\,/\,(3-\lambda)$ and $\phi \simeq 0.83$, if evaluated at $r = 0.04$ and $\lambda = 0.50$.

4.1 Setup

Let us assume that, in every period, a randomly selected fraction $\omega \in [0,1)$ of consumers cannot update their information set, while the the remaining fraction of consumers can update their information set. We call ω the degree of information rigidity. Our assumption simplifies the SI model of consumption by Reis (2006), who considers endogenous infrequent information updating.[16] Despite the simplification, as we will later show, the model predictions are very similar to Reis (2006).

Given infrequently updated information, consumers make decisions as rationally as they can. Suppose that a consumer updated his information in period t and does not obtain new information in $t+1$. In this case, he does not change his consumption in period $t+1$ since he recognizes no changes in the permanent income. He sticks to a consumption plan that he could follow in period t. Therefore, if the information is not updated in period $t+1$, any shock in period $t+1$ is unrecognized and absorbed by the consumer's saving. Reis (2006) refers to consumers who stick to their consumption plans as inattentive consumers.

More formally, an inattentive consumer who has period-t information chooses the ex ante optimal plan of consumption $\{C_{t+j,j}\}_{j=0}^{\infty}$, where $C_{t+j,j}$ is consumption chosen for the period $t+j$ with a j-period delay of information. Note that $C_{t,0}$ represents consumption that the consumer enjoys in period t with full information. This consumption $C_{t,0}$ must be equivalent to the optimal consumption under the RE model. If the consumer does not receive new information until period $t+j$, the consumer chooses $C_{t+j,j}$ that was planned in period t. Note also that $C_{t+j,j} = C_{t,0}$ is satisfied because the inattentive consumer perceives no changes in his permanent income. Therefore, for $j = 1, 2, ...$, we have

$$C_{t+j,j} = C_{t,0} = rA_t + X_t^p. \tag{6}$$

Let $S_{t+j,j}$ be changes in the foreign asset holdings of the consumer in period $t+j$, conditional that his information was updated in period t but has not been updated until period $t+j$. Then, $S_{t+j,j}$ is given by

$$S_{t+j,j} = rA_{t+j} + X_{t+j} - C_{t+j,j}, \tag{7}$$

where A_{t+j} follows (1) evaluated at $C_{t+j} = C_{t+j,j}$. That is, $A_{t+j+1} = (1+r)\,A_{t+j} + X_{t+j} - C_{t+j,j}$.

While $S_{t+j,j}$ in (7) and the current account in the RE model given by (3) look similar, they

[16] In Reis (2006), consumers face the cost of obtaining and processing information and decide whether to update their information and recompute the optimal consumption plan. In our setting, the information updating is exogenously given.

differ from each other because of two reasons. First, $S_{t+j,j}$ absorbs all changes in endowment between t and $t+j$, together with returns of the unintended change in the foreign asset holdings. Using (6), we can rewrite $S_{t+j,j}$ as

$$\begin{aligned} S_{t+j,j} &= r\left(A_{t+j} - A_t\right) + X_{t+j} - X_t^p \\ &= r\left(\Delta A_{t+j} + ... + \Delta A_{t+1}\right) + \Delta X_{t+j} + ... + \Delta X_{t+1} + S_{t,0}, \text{ for } j = 0, 1, 2, ..., \end{aligned} \tag{8}$$

where $S_{t,0} = X_t - X_t^p$ which equals the current account under the RE model. Under SI, the inattentive consumer's consumption ($C_{t+j,j}$) does not respond to the unrecognized changes in endowment between periods t and $t+j$. In (8), saving absorbs all unrecognized changes in endowment ΔX_{t+1}, ΔX_{t+2},..., ΔX_{t+j}. Accordingly, changes in the inattentive consumer's foreign asset holdings also include returns from the unrecognized changes in endowment (i.e., $r\left(\Delta A_{t+j} + ... + \Delta A_{t+1}\right)$). We rewrite (8) recursively as[17]

$$S_{t+j,j} = (1+r)\, S_{t+j-1,j-1} + \Delta X_{t+j} \text{ for } j = 1, 2, 3, ... \tag{9}$$

The second reason why $S_{t+j,j}$ should be distinguished from the current account in the RE model is that changes in foreign asset holdings differ across inattentive consumers, depending on how they update their information. To obtain the current account in the SI model, we need to aggregate individual foreign asset holdings across all inattentive consumers. Based on the assumption of information updating, the current account in the SI model is

$$CA_t = (1-\omega) \sum_{k=0}^{\infty} \omega^k S_{t,k}, \tag{10}$$

where $S_{t,k}$ is the period-t changes in the inattentive consumer's foreign assets based on the information in period $t-k$. Using (9), $S_{t,k}$ can also be written as

$$S_{t,k} = (1+r)\, S_{t-1,k-1} + \Delta X_t, \tag{11}$$

where $S_{t-k,0} = X_{t-k} - X_{t-k}^p$.

In the SI model extended with imperfect capital mobility, that is, the hybrid SI model, (4) continues to hold:

$$CA_t^{HY} = (1-\lambda)\, CA_t. \tag{12}$$

Likewise, the aggregate consumption in the hybrid SI model is $C_t^{HY} = (1-\lambda)\, C_t + \lambda X_t$.[18]

[17] See Appendix A.2.

[18] Reis (2006) also provides the microfoundation for (12). In particular, consumers may stick to saving plans

4.2 Characterizing the SI models

We characterize current account and consumption dynamics in the SI models. We first establish lemmas under the pure SI model. We then discuss the hybrid SI model.

4.2.1 Persistence and volatility of the current account

The following lemma describes current account dynamics under the pure SI model:

Lemma 1 *Suppose that (i) consumers are inattentive consumers who update their information with the probability of* $1-\omega$ *every period; (ii) the preference assumptions to derive (2) hold; (iii)* ω *is sufficiently low such that* $\omega(1+r) < 1$*. Then, the current account is given by*

$$CA_t = \omega^* CA_{t-1} + (1-\omega) S_{t,0} + \omega \Delta X_t, \tag{13}$$

where $S_{t,0} = X_t - X_t^p$ *and* $\omega^* = \omega(1+r)$*.*

Suppose also that (iv) the net output growth follows a covariance-stationary AR(1) process with mean zero: $g_{Xt} = \phi g_{Xt-1} + \varepsilon_t$*, where* $\varepsilon_t \sim i.i.d.(0, \sigma^2)$*. Then,* ca_t *can be approximated by the AR(2) process:*

$$ca_t = (\omega^* + \phi) ca_{t-1} - (\omega^* \phi) ca_{t-2} + \frac{\omega^* - \phi}{1 + r - \phi} \varepsilon_t. \tag{14}$$

Proof: See the Appendix A.3. □

The first part of Lemma 1 indicates that the current account is written as the first-order difference equation with two driving forces. The first driving force is $S_{t,0}$, changes in foreign asset holdings under full information. The impact of $S_{t,0}$ becomes weaker as ω becomes higher. The second driving force is ΔX_t. A fraction ω of inattentive consumers with old information let their saving absorb unrecognized shocks to endowment. For this reason, ΔX_t appears in (13) with its coefficient ω. Also, recall that the effect of unrecognized changes in endowment on CA_t is carried over to the subsequent periods with interest earnings. Therefore, as $\omega^* = \omega(1+r)$ increases, the coefficient on CA_{t-1} becomes larger, making CA_t more persistent.

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and let their consumption respond to unrecognized shocks to endowment, instead of sticking to consumption plans and letting their saving respond to shocks. He refers to such consumers as inattentive savers. Reis (2006) shows that, if the costs of planning are not too small, it is optimal for inattentive savers not to re-plan their savings at all. This result suggests that inattentive savers behave like consumers without any access to the international capital market, since their consumption is perfectly correlated with endowment. If the initial assets of inattentive savers are zero, the presence of inattentive savers reproduces the same equation as (12).

As we turn to the second part of the lemma, ca_t follows the AR(2) process, generalizing (5) in the RE model. Indeed, substituting $\omega^* = \omega(1+r) = 0$ in (13) results in the AR(1) process $ca_t = \phi ca_{t-1} - \phi/(1+r-\phi)\,\varepsilon_t$. Comparing $ca_t = -\phi/(1+r-\phi)\sum_{j=0}^{\infty}\phi^j \varepsilon_{t-j}$ with $g_{Xt} = \sum_{j=0}^{\infty}\phi^j \varepsilon_{t-j}$ implies $ca_t = -\phi/(1+r-\phi)\, g_{Xt}$, reproducing (5).

The following proposition summarizes the persistence and volatility of the current account:

Proposition 1 (Current account dynamics under the pure SI model when $\mu = 0$) *Suppose that the assumptions (i) – (iv) in Lemma 1 hold. Then, the current account has following properties:*

1. *Persistence*
$$\rho_{ca}^{SI} = \frac{\omega^* + \phi}{1 + \omega^* \phi} \geq \rho_{ca}^{RE} = \phi, \tag{15}$$
where the strict inequality holds if and only if $\omega > 0$ and $\omega^* \neq \phi$.

2. *Volatility*
$$V_{ca}^{SI} = \sqrt{\frac{1 + \omega^* \phi}{(1 - \omega^* \phi)\left[1 - (\omega^*)^2\right]}}\frac{|\omega^* - \phi|}{1 + r - \phi}. \tag{16}$$

Proof: The results immediately follow from the first-order autocorrelation and variance of the AR(2) process (14) provided in Lemma 1.□

The first part of Proposition 1 shows that the persistence of ca_t is increasing in ω^* so that the pure SI model can generate a persistent current account even when the net output growth is not persistent. The upper-left panel of Figure 1 shows ρ_{ca}^{SI} against ω.[19] The blue line is ρ_{ca}^{SI} under $\phi = 0.20$, while the red line is ρ_{ca}^{SI} under $\phi = 0.80$. We reconfirm that persistence of the current account increases with ω, regardless of the value of ϕ, except for the case of $\omega^* = \phi$. If ω^* happens to equal ϕ, the coefficient on ε_t is zero in (14) and the current account is constant for all t.

The second part of the proposition implies that the pure SI model can also generate the volatile current account. Here, (16) generalizes the expression for V_{ca}^{RE} with non-zero ω^*. The equation also implies that V_{ca}^{SI} changes discontinuously at $\omega^* = \phi$ (or $\omega = \phi/(1+r)$). The upper-right panel of Figure 1 plots the volatility of the current account against ω. The volatility decreases with ω if $\omega^* < \phi$ and increases with ω if $\omega^* > \phi$. When $\phi = 0.20$, the blue line shows that the volatility increases with ω over a wide range of ω. By contrast,

[19] Here, we set $r = 0.04$ to plot the curves. We also choose the range of $\omega \in [0, 0.9615]$. The upper bound is strictly but only slightly lower than $1/(1+r)$, ensuring the stationarity of the current account.

as shown in the red line, when $\phi = 0.80$, the volatility increases with ω over a very narrow range of ω.

4.2.2 Persistence and volatility of changes in consumption

We next discuss consumption dynamics in the pure SI model. Using the model with endogenous infrequent information updating, Reis (2006) demonstrates that his SI model of consumption can successfully generate persistent changes in consumption. We confirm consumption dynamics under exogenous infrequent information updating. In the next lemma, we analytically derive the stochastic process of Δc_{t+1}:

Lemma 2 *Suppose that the assumptions (i) – (iii) in Lemma 1 hold. Then, changes in the consumption are given by*

$$\Delta C_{t+1} = \omega^* \Delta C_t + (1 - \omega) \Delta \mathbb{E}_{t+1} X^p_{t+1}. \tag{17}$$

Suppose also that the assumption (iv) in Lemma 1 holds. Then, Δc_{t+1} can be approximated by the AR(1) process:

$$\Delta c_{t+1} = \omega^* \Delta c_t + (1 - \omega) \frac{1 + r}{1 + r - \phi} \varepsilon_{t+1}. \tag{18}$$

Proof: See the Appendix A.4. □

Using Lemma 2, we have the following proposition about the persistence and volatility of changes in consumption:

Proposition 2 (Consumption dynamics under the pure SI model when $\mu = 0$) *Suppose that the assumptions (i) – (iv) in Lemma 1 hold. Then, changes in consumption have the following properties:*

1. *Persistence*

$$\rho^{SI}_{\Delta c} = \omega^* \geq \rho^{RE}_{\Delta c} = 0, \tag{19}$$

   where the strict inequality holds if and only if $\omega > 0$.

2. *Volatility*

$$V^{SI}_{\Delta c} < V^{RE}_{\Delta c}, \tag{20}$$

   as long as $\omega < 2/\left(1 + (1 + r)^2\right)$.

Proof: The results immediately follow from the first-order autocorrelation and variance of the AR(1) process (18) provided in Lemma 2.□

In the first part of Proposition 2, a one-to-one relationship between $\rho^{SI}_{\Delta c}$ and ω^* comes from the fact that the first order autocorrelation of the AR(1) process corresponds to its AR coefficient. Therefore, the SI model can generate persistent changes in consumption if ω is calibrated to match with the data. For example, when $\omega = 0.24$ and $r = 0.04$, $\rho^{SI}_{\Delta c} = (1 + r)\,\omega = 0.25$ (see also the lower-left panel of Figure 1).

The second part of the proposition implies that $V^{SI}_{\Delta c}$ is lowered by ω. Therefore, the pure SI model can better predict the volatility of changes in consumption than the pure RE model. Under the assumptions (i) – (iv) in Lemma 1, $V^{SI}_{\Delta c}$ can be expressed as $V^{SI}_{\Delta c} = \Omega V^{RE}_{\Delta c}$, where $\Omega = (1 - \omega) / \sqrt{1 - (\omega^*)^2}$. The condition $\omega < 2/\left(1 + (1 + r)^2\right)$ in the proposition corresponds to $\Omega < 1$ so that $V^{SI}_{\Delta c} < V^{RE}_{\Delta c}$ holds. Under a sufficiently small value of r, this condition for ω is only slightly more restrictive than the assumption (iii) in Lemma 1, namely, $\omega\,(1 + r) < 1$. For example, if $r = 0.04$, the current condition $\omega < 2/\left(1 + (1 + r)^2\right) = 0.961$ and the assumption (iii) $\omega < 1/(1 + r) = 0.962$ are very close to each other in terms of the range of ω. The lower-right panel of Figure 1 plots the curve for $V^{SI}_{\Delta c}$ when $\phi = 0.20$ and 0.80. For $\phi = 0.20$, the volatility of Δc_t is 1.21 at $\omega = 0$. Overall, $V^{SI}_{\Delta c}$ decreases with ω for a wide range of ω. Consequently, $V^{SI}_{\Delta c}$ is likely to be smaller than $V^{RE}_{\Delta c}$. We observe a similar pattern for $\phi = 0.80$, though the magnitude of V^{SI}_{ca} is different from the previous case.

We have two additional remarks on consumption dynamics. First, not surprisingly, the dynamic properties of changes in consumption are very close to those in Reis (2006). His proposition 2 states that, when the maximum length of time during which consumers are inattentive is q periods, changes in consumption follow the MA(q) process with monotonically decreasing MA coefficients. In our SI model, the maximum length of time of being inattentive is infinity and the MA(∞) representation of the AR(1) process (18) implies that MA coefficients are exponentially decaying.

Second, as Reis (2006) argues, the representative-agent habit formation model can be an alternative explanation for persistent changes in consumption. It can be shown analytically that the current account in the habit formation model is the observational equivalent to the current account in the SI model. In particular, if the period utility in the habit formation model is given by $u(C_t - \gamma C_{t-1})$ and the habit parameter γ is equal to ω^*, the current account in the habit formation model follows the same stochastic process as that in our SI model. Therefore, the two models are indistinguishable in the aggregate data.[20] In the micro data,

[20] See also Carroll, Slacalek, and Sommer (2011) for the similarity between the habit formation model and their "sticky expectations" model.

however, there is mixed evidence for the presence of habit formation.[21] In addition, while the structure of SI models suggests disagreements about expectations, some empirical studies based on the micro survey data support such disagreements about expectations on main economic variables. For example, Dovern, Fritsche, and Slacalek (2012) report disagreement among professionals for main economic indicators, including GDP growth in G7 countries. Mankiw, Reis, and Wolfers (2003) and Coibion, Gorodnichenko, and Kumar (2018) find much stronger disagreement among economic agents such as households and firms than among professional forecasters. While Gruber (2004) finds that the representative-agent habit formation model performs better than the model without habits in predicting the current account dynamics, the better performance of his model may also reflect the presence of SI. An advantage of our SI model is that the explanation based on SI is broadly in line with the above evidence from the micro data.

4.2.3 Impulse responses

To better understand the current account dynamics in the SI model, it is helpful to investigate the impulse response functions. Figure 2 plots the impulse response functions of g_{Xt}, ca_t, and Δc_t to one unit increase in ε_t. In the leftmost panel, the response of g_{Xt} decays quickly, because we set ϕ at 0.20. In the middle and right panels, we compare the response of ca_t and Δc_t under the RE model ($\omega = 0$) and the SI model ($\omega = 0.20$ or 0.80).

Let us first consider the impulse response functions of ca_t and Δc_t under the RE model ($\omega = 0$). As shown in the blue line in the middle panel of Figure 2, the current account declines in response to ε_t. Because the shock has a positive permanent effect on endowment, consumers' permanent income increases more than the current endowment. In this case, increases in consumption at the impact period are larger than those in endowment at the same period. As a result, the economy runs current account deficits.

How do the impulse responses differ in the SI model ($\omega > 0$)? When $\omega = 0.20$, the current account is nearly constant, as the coefficient on ε_t in (14) is close to zero. To perceive the intuition, recall that inattentive consumers let their saving absorb unrecognized shocks between periods of planning. Even though a permanent effect on endowment increases the permanent income of all consumers, some consumers do not reduce their saving. Instead, they unintentionally increase their foreign asset holdings. The unintended increases in foreign asset holdings offset reductions in foreign asset holdings resulting from a permanent shock to endowment.

If the degree of information rigidity is sufficiently high (e.g., $\omega = 0.8$), the current account

[21] For example, see Dynan (2000) and Guariglia and Rossi (2002), among others.

increases. In response to a positive shock ε_t, unintended increases in foreign asset holdings exceed decreases in foreign asset holdings. In this case, the increases in consumption are smaller than those in endowment at the impact period. As a result, the economy runs the current account surplus.

4.2.4 The hybrid SI model

The following proposition summarizes the persistence and volatility of the current account:

Proposition 3 (Current account dynamics under the hybrid SI model when $\mu = 0$) *Suppose that all assumptions in Lemma 1 hold. Suppose also that (v) a fraction λ of consumers are hand-to-mouth consumers who have no access to the international financial market. Then, the current account has the following properties:*

1. *Persistence*
$$\rho_{ca}^{HY\text{-}SI} = \frac{\omega^* + \phi}{1 + \omega^* \phi} = \rho_{ca}^{SI}. \tag{21}$$

2. *Volatility*
$$V_{ca}^{HY\text{-}SI} \leq V_{ca}^{SI}, \tag{22}$$
where the strict inequality holds if and only if $\lambda > 0$ and $\omega^* \neq \phi$

Proof: The results immediately follow from the AR(2) process (14) and $ca_t^{HY} = (1 - \lambda)\, ca_t$ in the hybrid SI model. □

Figure 3 plots the persistence and volatility of the current account and changes in consumption against ω under the pure and hybrid SI models. As in the previous section, we again set $\lambda = 0.50$ for the hybrid SI model. The dashed line in Figure 3 corresponds to the hybrid SI model with $\lambda = 0.50$, while the solid line points to the pure SI model (i.e., $\lambda = 0$).

For persistence, $\rho_{ca}^{HY\text{-}SI} = \rho_{ca}^{SI}$ holds so that the hybrid SI model continues to be able to generate a persistent current account as in the pure SI model, even if imperfect capital mobility is assumed. This result occurs because the proportionality of ca_t^{HY} to ca_t continues to hold in the hybrid SI model. As a result, the curve for $\rho_{ca}^{HY\text{-}SI}$ traces out the upward-sloping curve for ρ_{ca}^{SI} in the upper-left panel of Figure 3.

For volatility, the hybrid SI model predicts a less volatile current account than the pure SI model does. This is again because the proportionality of ca_t^{HY} to ca_t holds in the hybrid SI model. The proportionality of ca_t^{HY} to ca_t implies that $V_{ca}^{HY\text{-}SI} = (1 - \lambda)\, V_{ca}^{SI}$ as in the RE models. In fact, the dashed line in the upper-right panel of Figure 3 indicates that

$V_{ca}^{HY\text{-}SI}$ is low in comparison to the solid line. However, $V_{ca}^{HY\text{-}SI}$ can increase with ω as long as $\omega \in (\phi/(1+r), 1)$, as in the case of the pure SI model. When ϕ takes a low value and ω is sufficiently large, the current account can be volatile even in the hybrid SI model.

How can we describe the persistence and volatility of changes in the aggregate consumption under the hybrid SI model? Recall that Δc_{t+1}^{HY} is approximated as the weighted average, $\Delta c_{t+1}^{HY} \simeq (1-\lambda)\Delta c_{t+1} + \lambda g_{Xt+1}$. From this definition, we have the following proposition about the persistence and volatility of changes in consumption in the hybrid SI model:

Proposition 4 (Consumption dynamics under the hybrid SI model when $\mu = 0$) *Suppose that all assumptions in Lemma 1 and the assumption (v) in Proposition 3 hold. Then, changes in the aggregate consumption have the following properties:*

1. *Persistence*

$$\rho_{\Delta c}^{HY\text{-}SI} = (1-\Lambda)\,\omega^* + \Lambda\phi, \tag{23}$$

where $\Lambda \in [0,1]$ *is a function of* $\lambda, \phi, \omega,$ and r, *given by*

$$\Lambda = \frac{\lambda^2 Var(g_{Xt}) + \lambda(1-\lambda)\,Cov(g_{Xt}, \Delta c_t)}{(1-\lambda)^2\,Var(\Delta c_t) + 2\lambda(1-\lambda)\,Cov(g_{Xt}, \Delta c_t) + \lambda^2 Var(g_{Xt})}. \tag{24}$$

2. *Volatility*

$$V_{\Delta c}^{HY\text{-}SI} = \sqrt{(1-\lambda)^2\left(\Omega V_{\Delta c}^{RE}\right)^2 + 2\lambda(1-\lambda)\sqrt{1-\phi^2}\left(\Omega_\phi V_{\Delta c}^{RE}\right) + \lambda^2}, \tag{25}$$

where $\Omega = (1-\omega)/\sqrt{1-(\omega^*)^2}$ and $\Omega_\phi = (1-\omega)/(1-\phi\omega^*)$.

Proof: See the Appendix A.5. □

The persistence $\rho_{\Delta c}^{HY\text{-}SI}$ is a weighted average of ω^* and ϕ. Therefore, the persistence of changes in the aggregate consumption no longer has a one-to-one relationship with ω^*. The lower-left panel of Figure 3 plots the persistence of changes in the aggregate consumption in the pure and the hybrid SI models. When ω is low, the dashed line is located above the solid line, increasing the overall persistence of changes in the aggregate consumption by means of the persistence of the net output growth. When ω is large, the dashed line is located below the solid line, preventing the overall persistence from increasing.[22] In other words, imperfect

[22] The dashed line in the lower-left panel of Figure 3 also shows that the persistence of changes in the aggregate consumption decreases with ω, even though an increase in ω raises the persistence of Δc_t, which is included in Δc_t^{HY}. The decline occurs because the weight Λ in (23) increases as ω increases.

capital mobility breaks the tight link between the persistence of changes in consumption and the degree of information rigidity. For example, even if ω increases, $\rho_{\Delta c}^{HY\text{-}SI}$ is kept lower than 0.4 for a wide range of ω. When ω is extremely large, however, ω^* becomes close to one. In this case, Δc_t becomes nonstationary in the limit and thus the persistence increases rapidly.

The expression for the volatility of changes in consumption is somewhat complicated. Nevertheless, the dashed line in the lower-right panel of Figure 3 shows that $V_{\Delta c}^{HY\text{-}SI}$ decreases with ω for a wide range of ω, though $V_{\Delta c}^{HY\text{-}SI}$ is insensitive to a change in ω. The shape of the curve implies that $V_{\Delta c}^{HY\text{-}SI}$ is also likely to be less than $V_{\Delta c}^{RE}$. In particular, unless ω is extremely large, $V_{\Delta c}^{HY\text{-}SI}$ falls short of 1.21, the value of $V_{\Delta c}^{RE}$ when $\phi = 0.20$ and $r = 0.04$. That is, our numerical example suggests that the hybrid SI model can better predict the volatility of changes in consumption than the pure RE model.

5 Assessment of the SI models

This section assesses the SI models in comparison to the RE models.

5.1 Methodology

We begin by slightly generalizing the pure SI model with the possibility of the non-zero mean growth rate of g_{Xt}, i.e., $\mu \neq 0$. While this generalization does not affect the steady state of Δc_t, the steady state value of ca_t is no longer zero but equal to $ca \equiv -\mu/(r-\mu)$.[23] To address the non-zero steady state, it would be convenient to introduce notations $\hat{ca}_t \equiv ca_t - ca$ and $\hat{g}_{Xt} \equiv g_{Xt} - \mu$. The following proposition generalizes the second part of Lemmas 1 and 2:

Proposition 5 (Current account and consumption dynamics under the hybrid SI model when $\mu \neq 0$) *Suppose that the assumptions (i) and (ii) in Lemma 1 hold. Suppose also that (iii)' ω is sufficiently low such that $\omega_\mu^* \equiv \omega(1+r)/(1+\mu) < 1$ where $\mu \in (-1, r)$; and (iv)' the net output growth follows a covariance-stationary AR(1) process: $\hat{g}_{Xt} = \phi \hat{g}_{Xt-1} + \varepsilon_t$, where $\varepsilon_t \sim i.i.d.(0, \sigma^2)$. Then, the stochastic process of $\hat{ca}_t$ and Δc_{t+1} can be approximated by*

$$\hat{ca}_t = \left(\omega_\mu^* + \phi\right) \hat{ca}_{t-1} - \left(\omega_\mu^* \phi\right) \hat{ca}_{t-2} + \frac{r}{r-\mu} \frac{\omega_\mu^* - \phi}{(1+r)/(1+\mu) - \phi} \varepsilon_t, \tag{26}$$

[23] See (40) in Appendix A.3.2. If the net output has a positive deterministic trend, the economy is sustainable under the current account deficit in the steady state.

and

$$\Delta c_{t+1} = \omega_{\mu}^{*} \Delta c_{t} + (1-\omega) \frac{r}{r-\mu} \frac{(1+r)(1+\mu)}{1+r-\phi(1+\mu)} \varepsilon_{t+1}, \tag{27}$$

respectively.

Proof: See the Appendix A.6. □

As in the results in Lemmas 1 and 2, the current account and changes in consumption follow the AR(2) and AR(1) processes, respectively. Their AR coefficients, however, differ from the case of $\mu = 0$, given in Lemmas 1 and 2. Equations (26) and (27) are applicable to the RE models with $\omega = 0$ and can easily be extended to the hybrid SI model with $\lambda \in [0, 1)$. In the proposition, we impose a weak condition that $\mu > -1$ to ensure ω_{μ}^{*} is positive. We also impose another, but somewhat strong, condition that the net output grows at a slower rate μ than the foreign asset holdings: $\mu < r$. We require this assumption to ensure the stationarity of the non-financial permanent income scaled by the net output.[24] A higher μ affects the moments of our interest as follows. First, a higher μ decreases the persistence of the current account and changes in consumption, since it reduces ω_{μ}^{*}. Second, a higher μ amplifies shocks through an increase in $r/(r-\mu)$, common to (26) and (27). This effect increases the volatility of ca_t and Δc_t.

Before we discuss the performance of the SI models, let us quickly reconfirm the poor performance of the RE models under nonzero μ. The left panel of Table 3 reports the four theoretical moments implied by the pure RE model. They are inconsistent with the actual moments (shown in the most right panel) even if nonzero μ is taken into account. On the cross-country average, the pure RE model underpredicts the persistence and the volatility of $\hat{ca}_t$: 0.17 in theory and 0.82 in data for persistence and 0.44 in theory and 2.30 in data for volatility. Turning to consumption, the pure RE model underpredicts the persistence of Δc_t (zero in theory and 0.25 in data) and overpredicts the volatility of Δc_t (2.11 in theory and 1.02 in data). Note that μ is positive in all countries and thus the predicted volatility of Δc_t becomes much higher than the value discussed in Section 2 ($V_{\Delta c}^{HY\text{-}RE} = 1.17$ under $\mu = 0$).

For the case of the hybrid RE model, we estimate the degree of imperfect capital mobility, λ, using the data of 16 developed OECD countries listed in Table 1. In particular, we employ the Bayesian minimum distance estimation framework considered in Inoue and Shintani (2018). In the classical minimum distance estimation, we aim to match the sample moments

[24] To understand the stationarity, consider the non-financial permanent income scaled by the net output, $X_t^p/X_t = r/(1+r)\sum_{j=0}^{\infty}(1+r)^{-j}\mathbb{E}_t(X_{t+j}/X_t) = r/(1+r) + r/(1+r)\sum_{j=1}^{\infty}(1+r)^{-j}\mathbb{E}_t\left[\exp\left(\sum_{k=1}^{j} g_{Xt+k}\right)\right]$. In the nonstochastic steady state, the non-financial permanent income scaled by the net output reduces to $r/(1+r)\sum_{j=0}^{\infty}[(1+\mu)/(1+r)]^j$. For this expression to be non-explosive, μ must be lower than r. See also Campbell and Deaton (1989).

and theoretical moments by minimizing the objective function

$$\widehat{q}(\theta) = \frac{1}{2}(\hat{\gamma} - f(\theta))'\hat{W}(\hat{\gamma} - f(\theta)) \tag{28}$$

where θ denotes the unknown parameter of interest ($\theta = \lambda$ in the current setting), $\hat{\gamma} = (\rho_{ca}^{data}, V_{ca}^{data}, \rho_{\Delta c}^{data}, V_{\Delta c}^{data})'$ is the vector of sample moments obtained from the data, $f(\theta) = (\rho_{ca}(\theta), V_{ca}(\theta), \rho_{\Delta c}(\theta), V_{ca}(\theta))'$ is the vector of the theoretical moments predicted from the model, and $\hat{W}$ is the weighting matrix. We compute the weighting matrix $\hat{W}$ from the inverse of the bootstrap covariance matrix of $\hat{\gamma} = (\rho_{ca}^{data}, V_{ca}^{data}, \rho_{\Delta c}^{data}, V_{\Delta c}^{data})'$ using the data of ca_t and Δc_t in each country.[25] For the Bayesian minimum distance estimation, the Markov Chain Monte Carlo (MCMC) method is used to obtain the (quasi-)posterior distribution of θ defined by

$$\frac{e^{-T\widehat{q}(\theta)}\pi(\theta)}{\int_{\Theta} e^{-T\widehat{q}(\theta)}\pi(\theta)d\theta} \tag{29}$$

where Θ is the parameter space of θ, $\pi(\theta)$ is the prior probability density, and T is the sample size. Since the cross-country average estimate of λ in Shibata and Shintani (1998) was around 0.5, the beta distribution with mean 0.5 and standard deviation 0.1 is used for the prior.

The middle panel of Table 3 reports the moments predicted by the hybrid RE model based on the posterior mean estimate of λ. In comparison to the pure RE model, the hybrid RE model can better explain consumption dynamics at the cost of undermining the predicted volatility of the current account. In particular, thanks to imperfect capital mobility, changes in consumption become more persistent and less volatile even under $\mu > 0$ ($\rho_{\Delta c}^{HY\text{-}RE} = 0.15$ and $V_{\Delta c}^{HY\text{-}RE} = 1.15$ on average). However, while the predicted persistence of the current account remains unchanged, the predicted volatility of the current account is much reduced in the hybrid RE model. In particular, the cross-country average of the predicted volatility of the current account is substantially reduced from 0.44 in the pure RE model to 0.06 in the hybrid RE model. In the single-country case, $V_{ca}^{HY\text{-}RE}$ is effectively zero in nine countries due to the extremely high estimates of λ.

In what follows, we employ the same Bayesian minimum distance estimator based on (29) combined with (28) to estimate $\theta = \omega$ for the pure SI model and $\theta = (\omega, \lambda)'$ for the hybrid SI model, respectively. For the prior of ω, we also use the beta distribution with mean 0.5 and standard deviation 0.1.

[25] A block bootstrap method with a block length of four is employed to compute the bootstrap covariance matrix.

5.2 Predictions of the SI models

The left panel of Table 4 shows the predictions of the pure SI model and the middle panel presents those of the hybrid SI model. The two models' predictions are based on our posterior mean estimates of ω and λ. For comparison, the right panel again reports the actual moments from the OECD countries.

The pure SI model exhibits a great improvement in comparison to the RE models. For example, the pure SI model can almost fully account for the four targeted moments in the Netherlands. In particular, the predicted moments are $(\rho_{ca}^{SI}, V_{ca}^{SI}, \rho_{\Delta c}^{SI}, V_{\Delta c}^{SI}) = (0.83, 2.09, 0.76, 0.84)$, as opposed to the actual moments: $(\rho_{ca}^{data}, V_{ca}^{data}, \rho_{\Delta c}^{data}, V_{\Delta c}^{data}) = (0.85, 2.07, 0.74, 0.81)$. The SI model also performs well in other countries, though not all moments are fully explained. For example, the predicted moments in Finland are $(\rho_{ca}^{SI}, V_{ca}^{SI}, \rho_{\Delta c}^{SI}, V_{\Delta c}^{SI}) = (0.83, 2.26, 0.77, 0.85)$, while the actual moments are $(0.92, 2.77, 0.34, 0.74)$. This outcome is a remarkable improvement in predictions relative to the RE models, because the RE models predict $(\rho_{ca}^{RE}, V_{ca}^{RE}, \rho_{\Delta c}^{RE}, V_{\Delta c}^{RE}) = (0.17, 0.37, 0.00, 2.19)$ and $(\rho_{ca}^{HY\text{-}RE}, V_{ca}^{HY\text{-}RE}, \rho_{\Delta c}^{HY\text{-}RE}, V_{\Delta c}^{HY\text{-}RE}) = (0.17, 0.00, 0.17, 1.01)$.

While the pure SI model performs well in predicting the persistence and volatility of the current account and the volatility of changes in consumption, it tends to overpredict the persistence of changes in consumption. In particular, $\rho_{\Delta c}^{SI}$ is 0.68 in the cross-country average but the average value of actual persistence $\rho_{\Delta c}^{data}$ is only 0.25. The overprediction stems from the one-to-one relationship between $\rho_{\Delta c}^{SI}$ and $\omega_{\mu}^{*} = \omega\,(1+r)\,/\,(1+\mu)$ in (27). That is, although a large ω helps the SI model explain the persistence and volatility of the current account, the one-to-one relationship between $\rho_{\Delta c}^{SI}$ and ω_{μ}^{*} also increases the persistence of changes in consumption far beyond the observed persistence.

The hybrid SI model breaks the tight link. The middle panel of Table 4 presents the theoretical moments generated by the hybrid SI model. The hybrid SI model continues to predict a persistent and volatile current account, but it can now explain consumption dynamics in both the persistence and volatility of changes in consumption. In the example of Finland, the prediction of the hybrid SI model is $(\rho_{ca}^{HY\text{-}SI}, V_{ca}^{HY\text{-}SI}, \rho_{\Delta c}^{HY\text{-}SI}, V_{\Delta c}^{HY\text{-}SI}) = (0.96, 2.51, 0.32, 0.69)$ as opposed to the data of $(0.92, 2.77, 0.34, 0.74)$. In terms of the cross-country average, the predicted persistence of changes in consumption is now suppressed to 0.33, which is fairly close to the data of 0.25.

5.3 Degrees of information rigidity and imperfect capital mobility

While the hybrid SI model achieves a fairly good model performance, we should note a caveat in the estimated values of ω and λ. The hybrid SI model can achieve good performance under relatively high degrees of information rigidity and imperfect capital mobility. Table 5 shows posterior mean estimates of ω and λ, along with 95 percent credible intervals computed from MCMC draws from the posterior distribution.[26] Since the hybrid RE model and the pure SI model can be viewed as a special case of the hybrid SI model with a restriction of $\omega = 0$ for the former, and of $\lambda = 0$ for the latter, the results for two models are also shown in Table 5. On average, ω is 0.66 in the pure SI model and 0.86 in the hybrid SI model. These values imply that the average duration of holding information until the next update is 2.9 years in the pure SI model and 7.1 years in the hybrid SI model.[27] The latter value seems extremely large compared to the average duration estimate of 1.3 years obtained by Mankiw and Reis (2007). Turning to the cross-country average of λ, the estimated λ is 0.86 for the hybrid RE model but it is reduced to 0.54 in the hybrid SI model. The latter value is not extremely high in the consumption literature though it may be considered to be high compared to the estimates of some previous studies.[28]

An interpretation of the high degrees of information rigidity and imperfect capital mobility may be that the ICA model does not allow for other possible frictions and that the estimated parameters may reflect such frictions outside the model. Therefore, while the SI model continues to be a promising approach in explaining the current account, introducing other types of frictions and/or shocks into the SI models may result in more reasonable estimates for the degrees of information rigidity and imperfect capital mobility.

It is also of interest to compare the empirical performance of the hybrid SI model and competing models using a model selection criterion. In the context of Bayesian minimum distance estimation, Inoue and Shintani (2018) show the validity of using the quasi-marginal likelihood (QML) defined by $\int_{\Theta} e^{-T\widehat{q}(\theta)}\pi(\theta)d\theta$ for the consistent model selection.[29]

Table 6 reports QMLs of the hybrid RE, the pure SI, and the hybrid SI models.[30] Since the models with a larger value of QML should be selected, the hybrid SI models outperforms other two models in 13 out of 16 countries. For the remaining three countries (Italy, the

[26] Posterior distribution is evaluated using the random walk Metropolis-Hastings algorithm with the number of MCMC draws being 200,000. To ensure the stationarity condition in the pure and hybrid SI models, draws are discarded when $0 < \omega_{\mu}^{*} < 1$ is violated.

[27] Given the annual data, the average duration of holding information until the next update can be computed from $(1 - 0.66)^{-1} = 2.9$ and $(1 - 0.86)^{-1} = 7.1$.

[28] For example, Campbell and Mankiw (1990) use the US data and estimate λ to range between 0.30 and 0.64. Reis (2006) estimates λ, considering SI explicitly. His estimate of λ is quite low, a value between 0.05 and 0.15.

[29] Here, 'quasi' in quasi-marginal likelihood implies that it differs from the standard marginal likelihood because there is no likelihood function in the minimum distance estimation.

[30] For the robustness, two alternative estimates of QMLs are reported. One is obtained using the modified harmonic mean estimator of Geweke (1999) and the other is obtained using Chib and Jeliazkov's (2001) estimator.

Netherlands, and the US), the pure SI model is selected. The hybrid RE model is not selected for any country. It may not be surprising that imperfect capital mobility leads to the good performance of the SI model because the hybrid SI model has one additional free parameter λ. However, this apparent result is not the case because the model selection based on QML penalizes when the number of parameters in the model increases (see Inoue and Shintani 2018). In addition, the fact that the hybrid RE model is not selected implies that imperfect capital mobility alone does not necessarily improve the predictions regarding the current account dynamics, unless information rigidity is incorporated.

6 Conclusion

This paper has incorporated sticky information (SI) into the intertemporal current account (ICA) model. The data of OECD countries suggest that the rational expectations (RE) model fails to explain the observed current account and consumption dynamics. Even if we extend the RE model with the imperfect capital mobility of Shibata and Shintani (1998), this hybrid RE model can account for consumption, but fails to explain the current account. To better understand current account dynamics, we studied how well SI could explain current account dynamics in the cases of perfect and imperfect capital mobility.

While the SI model makes a great improvement in predicting the persistence and volatility of the current account and the volatility of changes in consumption, it overpredicts the persistence of changes in consumption. The hybrid SI model extended with imperfect capital mobility performs fairly well in explaining the observed current account and consumption dynamics, as long as the degrees of information rigidities and imperfect capital mobility are sufficiently high. We obtained these findings from Bayesian minimum distance estimation framework applied to the data of the 16 OECD countries.

To reduce too much reliance on imperfect information and imperfect capital mobility, incorporating other possibilities in our hybrid SI model may be useful. Toward this end, it may be important to consider the production economy and to include other frictions in our model.[31] Consideration of other shocks, such as the world interest rate shock and the exchange rate shock, could also be a promising direction for future research.[32]

[31] One of the most important avenues of research may be the general equilibrium model with SI by Ekinci (2017), although he focuses on a two-country model rather than on small open economies.

[32] For example, see Bergin and Sheffrin (2000) and Kano (2009).

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A Appendix

A.1 The maximization problem and the optimality conditions

Our formal description of the consumer's maximization problem follows Mankiw and Reis (2007). Suppose that a consumer has the information set available in period t. We consider an inattentive consumer who receives the newest information only with the probability $1-\omega$ every period. Given the infrequent information updating and the information set in period t, he chooses a consumption plan to solve the following maximization problem:

$$
\begin{aligned}
V\left(A_t, X_t\right) &= \max_{\{C_{t+j,j}\}_{i=0}^{\infty}} \sum_{j=0}^{\infty} (\beta\omega)^j u\left(C_{t+j,j}\right) \qquad (30)\\
&\quad +\beta\left(1-\omega\right)\mathbb{E}_t \sum_{j=0}^{\infty} (\beta\omega)^j V\left(A_{t+j+1}, X_{t+j+1}\right), \\
\text{subject to } A_{t+j+1} &= \left(1+r\right)A_{t+j} + X_{t+j} - C_{t+j,j}, \quad \text{for } j = 0, 1, 2, ..., \qquad (31)
\end{aligned}
$$

where $V\left(A_t, X_t\right)$ is the value function of the consumer in period t. Using the information available in period t, he chooses the consumption plan $\{C_{t+j,j}\}_{j=0}^{\infty}$, where $C_{t+j,j}$ represents the amount of goods consumed in period $t+j$ but has predetermined j periods in advance. The value function is somewhat complicated since the plan is specified as consumption from period t and revised once he receives the new information. Other variables, parameters, and the function $u\left(C\right)$ are defined in the main text.

The first-order condition and the envelope condition are

$$
\begin{aligned}
u'\left(C_{t+j,j}\right) &= \beta\left(1-\omega\right)\mathbb{E}_t \sum_{k=0}^{\infty} \left[\beta\omega\left(1+r\right)\right]^k V'\left(A_{t+j+k+1}, X_{t+j+k+1}\right), \qquad (32)\\
V'\left(A_t, X_t\right) &= \beta\left(1-\omega\right)\left(1+r\right)\mathbb{E}_t \sum_{k=0}^{\infty} \left[\beta\omega\left(1+r\right)\right]^k V'\left(A_{t+k+1}, X_{t+k+1}\right), \qquad (33)
\end{aligned}
$$

for $j = 0, 1, 2, ...$, respectively. Here, $u'\left(C\right) = du\left(C\right)/dC$ and $V'\left(A_t, X_t\right)$ is the partial derivative with respect to the foreign asset. That is, $V'\left(A, X\right) = \partial V\left(A, X\right)/\partial A$.

Evaluating (32) at $j = 0$ yields $u'\left(C_{t,0}\right) = \beta\left(1-\omega\right)\mathbb{E}_t \sum_{k=0}^{\infty} \left[\beta\omega\left(1+r\right)\right]^k V'\left(A_{t+k+1}, X_{t+k+1}\right)$. This result implies

$$
V'\left(A_t, X_t\right) = \left(1+r\right)u'\left(C_{t,0}\right). \qquad (34)
$$

Rewriting (33) recursively, we have

$$\begin{aligned}
V'(A_t, X_t) &= \beta(1-\omega)(1+r)\mathbb{E}_t \sum_{k=0}^{\infty} [\beta\omega(1+r)]^k V'(A_{t+k+1}, X_{t+k+1}) \\
&= \beta(1-\omega)(1+r)\mathbb{E}_t V'(A_{t+1}, X_{t+1}) \\
&\quad + \beta\omega(1+r)\mathbb{E}_t \left\{ \beta(1-\omega)(1+r) \sum_{k=0}^{\infty} [\beta\omega(1+r)]^k \mathbb{E}_{t+1} V(A_{t+k+2}, X_{t+k+2}) \right\} \\
&= \beta(1-\omega)(1+r)\mathbb{E}_t V'(A_{t+1}, X_{t+1}) + \beta\omega(1+r)\mathbb{E}_t V'(A_{t+1}, X_{t+1}) \\
&= \beta(1+r)\mathbb{E}_t V'(A_{t+1}, X_{t+1}). \qquad (35)
\end{aligned}$$

Combining (34) and (35), we have the Euler equation that is standard in the RE model:

$$u'(C_{t,0}) = \beta(1+r)\mathbb{E}_t u'(C_{t+1,0}). \qquad (36)$$

We next consider the expected marginal utility $\mathbb{E}_t u'(C_{t+1,0})$. Update (32) by one period and set $j = 0$. Then, we have $u'(C_{t+1,0}) = \beta(1-\omega)\mathbb{E}_{t+1} \sum_{k=0}^{\infty} [\beta\omega(1+r)]^k V'(A_{t+k+2}, X_{t+k+2})$. By the law of iterated expectations,

$$\begin{aligned}
\mathbb{E}_t u'(C_{t+1,0}) &= \beta(1-\omega)\mathbb{E}_t \sum_{k=0}^{\infty} [\beta\omega(1+r)]^k V'(A_{t+k+2}, X_{t+k+2}) \\
&= u'(C_{t+1,1}).
\end{aligned}$$

Therefore, along with the assumption of $\beta(1+r) = 1$, (36) implies

$$C_{t+j,j} = C_{t,0} \text{ for } j = 1, 2, ... \qquad (37)$$

We note that the optimal consumption in period t under the SI and RE models must be the same because the information used to determine the optimal period-t consumption is identical. Therefore, (2) and (37) imply (6) in the main text: $C_{t+j,j} = rA_t + X_t^p$, for $j = 0, 1, 2, ...$

A.2 Inattentive consumer's saving

Using (6), it is straightforward to derive (9) in the main text:

$$\begin{aligned}
S_{t+j,j} &= A_{t+j+1} - A_{t+j} = rA_{t+j} + X_{t+j} - C_{t+j,j} \\
&= r(A_{t+j} - A_t) + X_{t+j} - X_t^p \\
&= \underbrace{r(A_{t+j} - A_{t+j-1})}_{s_{t+j-1,j-1}} + X_{t+j} - X_{t+j-1} + \underbrace{r(A_{t+j-1} - A_t) + X_{t+j-1} - X_t^p}_{s_{t+j-1,j-1}} \\
&= (1+r) S_{t+j-1,j-1} + \Delta X_{t+j} \text{ for } j = 1, 2, 3, ... \qquad (38)
\end{aligned}$$

A.3 Proof of Lemma 1

A.3.1 Derivation of (13)

To obtain the current account in the economy, we aggregate all individual savings over information differing across households. Notice that $S_{t,k}$ is the period-t saving of the inattentive consumers who updated their information k periods ago. Using (38), we have an individual's saving in period t:

$$\begin{aligned} S_{t,k} &= (1+r)\,S_{t-1,k-1} + \Delta X_t = (1+r)\left[(1+r)\,S_{t-2,k-2} + \Delta X_{t-1}\right] + \Delta X_t \\ &= (1+r)^2\,S_{t-2,k-2} + \Delta X_t + (1+r)\,\Delta X_{t-1} \\ &= \ldots \\ &= (1+r)^k\,S_{t-k,0} + \Delta X_t + (1+r)\,\Delta X_{t-1} + \ldots + (1+r)^{k-1}\,\Delta X_{t-k+1}, \end{aligned}$$

where $S_{t-k.0} = X_{t-k} - X_{t-k}^p$ for $k = 1, 2, 3, \ldots$. The distribution of $S_{t,k}$ follows (10) in the main text so that the current account is aggregated by

$$\begin{aligned} CA_t = \; & (1-\omega)\,S_{t,0} \\ & + (1-\omega)\,\omega\,(1+r)\,S_{t-1,0} + (1-\omega)\,\omega\Delta X_t \\ & + (1-\omega)\,\omega^2\,(1+r)^2\,S_{t-2,0} + (1-\omega)\,\omega^2\Delta X_t + (1-\omega)\,\omega^2\,(1+r)\,\Delta X_{t-1} \\ & + \ldots. \end{aligned}$$

Using the definition of $\omega^* = \omega\,(1+r)$, this equation can be rearranged as

$$\begin{aligned} CA_t &= (1-\omega)\sum_{k=0}^{\infty}(\omega^*)^k S_{t-k,0} \\ &\quad + \omega\,(1-\omega)\sum_{k=0}^{\infty}\omega^k\Delta X_t + \omega\omega^*\,(1-\omega)\sum_{k=0}^{\infty}\omega^k\Delta X_{t-1} + \omega(\omega^*)^2\,(1-\omega)\sum_{k=0}^{\infty}\omega^k\Delta X_{t-2} + \ldots \\ &= (1-\omega)\sum_{k=0}^{\infty}(\omega^*)^k S_{t-k,0} + \omega\left[\Delta X_t + \omega^*\Delta X_{t-1} + (\omega^*)^2\Delta X_{t-2} + \ldots\right] \\ &= \sum_{k=0}^{\infty}(\omega^*)^k\left[(1-\omega)\,S_{t-k,0} + \omega\Delta X_{t-k}\right]. \end{aligned}$$

Assume that $\omega^* = \omega\,(1+r) < 1$. Then, with the lag operator L, $CA_t = (1-\omega^* L)^{-1}\left[(1-\omega)\,S_{t,0} + \omega\Delta X_t\right]$. This equation is equivalent to (13) in Lemma 1.

A.3.2 Derivation of (14)

In the proof, we derive the stochastic process of ca_t under the generalized case of non-zero μ. It is convenient because the general case allows us to derive (26) and (27) in Proposition 7. To prove the second part of Lemma 1, we divide both sides of (13) by X_{t-1}:

$$\exp(g_{Xt})\, ca_t = \omega^* ca_{t-1} + (1-\omega)\exp(g_{Xt})\, s_{t,0} + \omega\left[\exp(g_{Xt}) - 1\right], \tag{39}$$

where $s_{t,0} \equiv S_{t,0}/X_t$. We note that the steady state value of $s_{t,0}$ equals the steady state value of ca_t because $S_{t,0}$ is identical to the current account under the RE model. Let ca be the steady state value of ca_t. In the steady state, (39) becomes

$$\exp(\mu)\cdot ca = \omega^* ca + (1-\omega)\exp(\mu)\, ca + \omega\left[\exp(\mu) - 1\right].$$

Noting that $\exp(\mu) = 1 + \mu$, $\omega^* = \omega(1+r)$, we can solve the above equation for ca as follows:

$$ca = -\frac{\mu}{r-\mu}. \tag{40}$$

That is, ca is zero if $\mu = 0$. In addressing the case of non-zero μ, it is convenient to introduce the deviations of a variable from the mean:

$$\hat{ca}_t = ca_t - ca,\ \hat{s}_{t,0} = s_{t,0} - ca, \text{ and } \hat{g}_{Xt} = g_{Xt} - \mu.$$

The first-order Taylor expansion of both sides of (39) around the steady state is

$$\exp(\mu)\cdot \hat{ca}_t + \left[\exp(\mu)\, ca\right]\hat{g}_{Xt} = \omega^* \hat{ca}_{t-1} + (1-\omega)\exp(\mu)\,\hat{s}_{t,0} + (1-\omega)\left[\exp(\mu)\, ca\right]\hat{g}_{Xt} + \omega\exp(\mu)\,\hat{g}_{Xt}.$$

Arranging terms yields

$$\hat{ca}_t = \omega_\mu^* \hat{ca}_{t-1} + (1-\omega)\,\hat{s}_{t,0} + \omega(1-ca)\,\hat{g}_{Xt}, \tag{41}$$

where $\omega_\mu^* = \omega(1+r)/\exp(\mu) = \omega(1+r)/(1+\mu)$.

We rewrite the last two terms of (41). As a preparation, note that $s_{t,0} = 1 - X_t^p/X_t$ since $S_{t,0} = X_t - X_t^p$. Here, we have

$$\frac{X_t^p}{X_t} = \frac{r}{1+r}\sum_{j=0}^{\infty}\left(\frac{1}{1+r}\right)^j \mathbb{E}_t\left(\frac{X_{t+j}}{X_t}\right). \tag{42}$$

Focusing on each X_{t+j}/X_t inside the summation, we have the first-order Taylor expansions of X_{t+j}/X_t:

$$
\begin{aligned}
\frac{X_t}{X_t} &= (1+\mu)^0 \times 1 \\
\frac{X_{t+1}}{X_t} &\simeq (1+\mu)^1 \times (1+\hat{g}_{Xt+1}) \\
\frac{X_{t+2}}{X_t} &\simeq (1+\mu)^2 \times (1+\hat{g}_{Xt+1}+\hat{g}_{Xt+2}) \\
&\quad ... \\
\frac{X_{t+j}}{X_t} &\simeq (1+\mu)^j \times (1+\hat{g}_{Xt+1}+\hat{g}_{Xt+2}+...+\hat{g}_{Xt+j}) .
\end{aligned}
$$

Substituting these approximants into X_t^p/X_t in (42), we have

$$
\begin{aligned}
\frac{X_t^p}{X_t} &\simeq \frac{r}{1+r}\sum_{j=0}^{\infty}\left(\frac{1+\mu}{1+r}\right)^j + \frac{r}{1+r}\sum_{j=1}^{\infty}\left(\frac{1+\mu}{1+r}\right)^j \mathbb{E}_t\hat{g}_{Xt+1} + \frac{r}{1+r}\sum_{j=2}^{\infty}\left(\frac{1+\mu}{1+r}\right)^j \mathbb{E}_t\hat{g}_{Xt+2} + ... \\
&= \frac{r}{r-\mu} + \frac{r}{r-\mu}\left(\frac{1+\mu}{1+r}\right)\mathbb{E}_t\hat{g}_{Xt+1} + \frac{r}{r-\mu}\left(\frac{1+\mu}{1+r}\right)^2 \mathbb{E}_t\hat{g}_{Xt+2} + ... \\
&= \frac{r}{r-\mu} + \frac{r}{r-\mu}\sum_{j=1}^{\infty}\left(\frac{1+\mu}{1+r}\right)^j \mathbb{E}_t\hat{g}_{Xt+j} \\
&= \frac{r}{r-\mu} + \frac{r}{r-\mu}\frac{\phi}{(1+r)/(1+\mu)-\phi}\hat{g}_{Xt},
\end{aligned}
\tag{43}
$$

where the last line is due to the AR(1) process of $\hat{g}_{Xt}$.

Equation (43) provides the expression of the second term of (41). Since $\hat{s}_{t,0} = 1 - X_t^p/X_t - ca$, the second term of (41) is given by

$$
(1-\omega)\,\hat{s}_{t,0} = -(1-\omega)\frac{r}{r-\mu}\frac{\phi}{(1+r)/(1+\mu)-\phi}\hat{g}_{Xt}. \tag{44}
$$

Plugging in (40) and (44) into (41) yields

$$
\begin{aligned}
c\hat{a}_t &= \omega_\mu^* c\hat{a}_{t-1} - (1-\omega)\frac{r}{r-\mu}\frac{\phi}{(1+r)/(1+\mu)-\phi}\hat{g}_{Xt} + \omega\frac{r}{r-\mu}\hat{g}_{Xt} \\
&= \omega_\mu^* c\hat{a}_{t-1} + \frac{r}{r-\mu}\left[\omega - (1-\omega)\frac{\phi}{(1+r)/(1+\mu)-\phi}\right]\hat{g}_{Xt} \\
&= \omega_\mu^* c\hat{a}_{t-1} + \frac{r}{r-\mu}\frac{\omega_\mu^*-\phi}{(1+r)/(1+\mu)-\phi}\hat{g}_{Xt}.
\end{aligned}
$$

Using $\hat{g}_{Xt} = \phi\hat{g}_{Xt-1} + \varepsilon_t = (1-\phi L)^{-1}\varepsilon_t$, we can further rewrite the above equation as

$$
c\hat{a}_t = \left(\omega_\mu^* + \phi\right)c\hat{a}_{t-1} - \left(\omega_\mu^*\phi\right)c\hat{a}_{t-2} + \frac{r}{r-\mu}\frac{\omega_\mu^*-\phi}{(1+r)/(1+\mu)-\phi}\varepsilon_t, \tag{45}
$$

which proves (26) in the main text. Imposing $\mu = 0$ also yields (14) in the main text.

A.4 Proof of Lemma 2

A.4.1 Derivation of (17)

To obtain changes in the aggregate consumption ΔC_{t+1}, we aggregate all individual changes in consumption between the periods t and $t+1$. Notice that consumers do not change their individual consumption if they do not realize shocks between period t and $t+1$ (i.e., $C_{t+1,k+1} - C_{t,k} = 0$ for any $k \geq 0$). Therefore, for aggregation, it suffices to consider only consumers who receive the newest information in period $t+1$. When aggregating changes in their consumption, however, we need to take into account the history of information updating. For this reason, we first consider a sequence of changes in consumption $\{C_{t+j+1,0} - C_{t+j,j}\}_{j=0}^{\infty}$, given the foreign asset holdings A_t. This sequence consists of changes in consumption for an individual consumer, conditional on the fact that he receives no additional information between t and $t+j+1$. We derive the expression for the changes in individual consumption as accumulated forecast errors. We then cross-sectionally aggregate changes in individual consumption differing across histories of individual information updating. The aggregation is made based on the distribution of information updating.

Consider a sequence of changes in consumption $\{C_{t+j+1,0} - C_{t+j,j}\}_{j=0}^{\infty}$. The simplest is the case of $j = 0$ (i.e., $C_{t+1,0} - C_{t,0}$). If a consumer with information in period t updates the information in period $t+1$, the changes in consumption are the same as those in the RE model:

$$\begin{aligned} C_{t+1,0} - C_{t,0} &= r\left(A_{t+1} - A_t\right) + \left(X_{t+1}^p - X_t^p\right) \\ &= rS_{t,0} + \left(X_{t+1}^p - X_t^p\right) \\ &= rX_t + \left(X_{t+1}^p - (1+r)\, X_t^p\right) \\ &= \Delta\mathbb{E}_{t+1} X_{t+1}^p, \end{aligned} \tag{46}$$

where the first equality uses the optimal consumption given by $C_{t,0} = rA_t + X_t^p$ (See (6) in the main text); the second equality arises from $A_{t+1} - A_t = S_{t,0}$; the third equality arises from $S_{t,0} = X_t - X_t^p$; and the final equality can be obtained from the definition of the non-financial permanent income $X_t^p = r/\,(1+r) \sum_{j=0}^{\infty} (1+r)^{-j}\, \mathbb{E}_t X_{t+j}$. Equation (46) indicates that changes in consumption in period $t+1$ equal unrecognized changes in permanent income.

Next, consider the case of $j = 1$. Suppose that a consumer with information in period t does not update his information set in period $t+1$, but updates the information in period $t+2$. Changes in consumption between periods $t+1$ and $t+2$ can analogously be calculated as

$$\begin{aligned} C_{t+2,0} - C_{t+1,1} &= C_{t+2,0} - C_{t,0} \\ &= r\left(A_{t+2} - A_{t+1} + A_{t+1} - A_t\right) + \left(X_{t+2}^p - X_{t+1}^p\right) + \left(X_{t+1}^p - X_t^p\right) \\ &= rS_{t+1,1} + \left(X_{t+2}^p - X_{t+1}^p\right) + rS_{t,0} + \left(X_{t+1}^p - X_t^p\right) \\ &= rS_{t+1,1} + \left(X_{t+2}^p - X_{t+1}^p\right) + \Delta\mathbb{E}_{t+1} X_{t+1}^p. \end{aligned} \tag{47}$$

Here, the third equality is based on the fact that $A_{t+2} - A_{t+1} = S_{t+1,1}$ because the consumer does not update information in period $t+1$. The last equality can be derived from (46). Furthermore, the first two terms of the right-hand side can be rewritten as

$$\begin{aligned} rS_{t+1,1} + \left(X^p_{t+2} - X^p_{t+1}\right) &= r\left[(1+r)\, S_{t,0} + \Delta X_{t+1}\right] + \left(X^p_{t+2} - X^p_{t+1}\right) \\ &= r\left[rX_t + X^p_{t+1} - (1+r)\, X^p_t\right] + \left[rX_{t+1} + \left(X^p_{t+2} - (1+r)\, X^p_{t+1}\right)\right] \\ &= r\Delta\mathbb{E}_{t+1}X^p_{t+1} + \Delta\mathbb{E}_{t+2}X^p_{t+2}, \end{aligned}$$

where the first equality is due to (38); the second equality is obtained from arranging terms with $S_{t,0} = X_t - X^p_t$; and the third equality is due to (46). Substituting the above equation into (47), we obtain changes in consumption when the consumer with information in period t updates information in period $t+2$:

$$C_{t+2,0} - C_{t+1,1} = \Delta\mathbb{E}_{t+2}X^p_{t+2} + (1+r)\,\Delta\mathbb{E}_{t+1}X^p_{t+1}. \tag{48}$$

This equation indicates that, if he updates the information in period $t+2$ but did not update it in period $t+1$, the changes in consumption include the unrecognized changes in permanent income in both periods $t+1$ and $t+2$.

For the general case of $j > 1$, we repeat the above calculation. The general expression of changes in individual consumption is

$$C_{t+j,0} - C_{t+j-1,j-1} = \Delta\mathbb{E}_{t+j}X^p_{t+j} + (1+r)\,\Delta\mathbb{E}_{t+j-1}X^p_{t+j-1} + ... + (1+r)^{j-1}\,\Delta\mathbb{E}_{t+1}X^p_{t+1}, \quad \text{for } j = 1, 2, ... \tag{49}$$

We now aggregate changes in consumption between t and $t+1$ across all consumers, using the distribution of inattentive consumers: $C_t = (1-\omega)\sum_{k=0}^{\infty}\omega^k C_{t,k}$. Recall that it is sufficient to consider only consumers who receive the newest information in period $t+1$. The fraction of information-updating consumers is $1-\omega$. Therefore, changes in the aggregate consumption become

$$\begin{aligned} \Delta C_{t+1} = (1-\omega)^2 \Big\{ &\Delta\mathbb{E}_{t+1}X^p_{t+1} \\ &+ \omega\left[\Delta\mathbb{E}_{t+1}X^p_{t+1} + (1+r)\,\Delta\mathbb{E}_t X^p_t\right] \\ &+ \omega^2\left[\Delta\mathbb{E}_{t+1}X^p_{t+1} + (1+r)\,\Delta\mathbb{E}_t X^p_t + (1+r)^2\,\Delta\mathbb{E}_{t-1}X^p_{t-1}\right] \\ &+ \omega^3\left[\Delta\mathbb{E}_{t+1}X^p_{t+1} + (1+r)\,\Delta\mathbb{E}_t X^p_t + (1+r)^2\,\Delta\mathbb{E}_{t-1}X^p_{t-1} + (1+r)^3\,\Delta\mathbb{E}_{t-2}X^p_{t-2}\right] + ... \Big\}. \end{aligned} \tag{50}$$

In the above equation, the first line in the curly brackets represents changes in consumption for consumers whose period-t consumption was $C_{t,0}$. The second line points to that for consumers whose period-t consumption was $C_{t,1}$ $(= C_{t-1,0})$. We can understand the remaining lines analogously. This equation can further be simplified to

$$\begin{aligned}
\Delta C_{t+1} &= (1-\omega)\left[(1-\omega)\sum_{k=0}^{\infty}\omega^k\Delta\mathbb{E}_{t+1}X_{t+1}^p\right. \\
&\quad + (1+r)\,\omega\,(1-\omega)\sum_{k=0}^{\infty}\omega^k\Delta\mathbb{E}_tX_t^p \\
&\quad \left. + (1+r)^2\,\omega^2\,(1-\omega)\sum_{k=0}^{\infty}\omega^k\Delta\mathbb{E}_{t-1}X_{t-1}^p + ...\right] \\
&= (1-\omega)\left[\Delta\mathbb{E}_{t+1}X_{t+1}^p + \omega^*\Delta\mathbb{E}_tX_t^p + (\omega^*)^2\Delta\mathbb{E}_{t-1}X_{t-1}^p + ...\right] \\
&= \frac{1-\omega}{1-\omega^*L}\Delta\mathbb{E}_{t+1}X_{t+1}^p,
\end{aligned} \tag{51}$$

where the second equality comes from $(1-\omega)\sum_{k=0}^{\infty}\omega^k = 1$. By multiplying $1-\omega^*L$ by both sides and arranging terms, we obtain (17) in the main text:

$$\Delta C_{t+1} = \omega^*\Delta C_t + (1-\omega)\,\Delta\mathbb{E}_{t+1}X_{t+1}^p.$$

A.4.2 Derivation of (18)

Turning to the derivation of (18), we divide both sides of (17) by X_t:

$$\Delta c_{t+1} = \omega^*\exp\left(-g_{Xt}\right)\Delta c_t + (1-\omega)\,\Delta\mathbb{E}_{t+1}\left(\frac{X_{t+1}^p}{X_t}\right). \tag{52}$$

We approximate each term in the right-hand side of (52). First, the first-order Taylor approximation of the first term is

$$\omega^*\exp\left(-g_{Xt}\right)\Delta c_t \simeq \omega^*\exp\left(-\mu\right)(\Delta c) + \omega^*\exp\left(-\mu\right)(\Delta c_t - \Delta c) - \frac{\omega^*}{1+\mu}(\Delta c)\,\hat{g}_{Xt},$$

where Δc is the steady state value of changes in consumption (divided by the net output). In the steady state, however, $\Delta c = 0$. Therefore, noting that $\exp\left(-\mu\right) = (1+\mu)^{-1}$ and $\omega_\mu^* \equiv \omega\,(1+r)\,/\,(1+\mu)$, we can simplify the above equation as

$$\omega^*\exp\left(-g_{Xt}\right)\Delta c_t \simeq \omega_\mu^*\Delta c_t. \tag{53}$$

The second term of the right-hand side of (52) includes $\mathbb{E}_{t+1}\left(X^p_{t+1}/X_t\right)$, which can be approximated by

$$\begin{aligned}\mathbb{E}_{t+1}\left(\frac{X^p_{t+1}}{X_t}\right) &= \frac{r}{1+r}\sum_{j=0}^{\infty}(1+r)^{-j}\,\mathbb{E}_{t+1}\left(\frac{X_{t+j+1}}{X_t}\right) \\ &= r\sum_{j=1}^{\infty}\left(\frac{1}{1+r}\right)^j\mathbb{E}_{t+1}\left(\frac{X_{t+j}}{X_t}\right) \\ &\simeq r\sum_{j=1}^{\infty}\left(\frac{1+\mu}{1+r}\right)^j\mathbb{E}_{t+1}\left(1+\hat{g}_{Xt+1}+\hat{g}_{Xt+2}+...+\hat{g}_{Xt+j}\right) \\ &= r\sum_{j=1}^{\infty}\left(\frac{1+\mu}{1+r}\right)^j + r\sum_{j=1}^{\infty}\left(\frac{1+\mu}{1+r}\right)^j\mathbb{E}_{t+1}\hat{g}_{Xt+1} + \left(\frac{1+\mu}{1+r}\right)r\sum_{j=1}^{\infty}\left(\frac{1+\mu}{1+r}\right)^j\mathbb{E}_{t+1}\hat{g}_{Xt+2}+... \\ &= \frac{r(1+\mu)}{r-\mu}+\frac{r(1+\mu)}{r-\mu}\sum_{j=0}^{\infty}\left(\frac{1+\mu}{1+r}\right)^j\mathbb{E}_{t+1}\hat{g}_{Xt+j+1}.\end{aligned}$$

Because $\hat{g}_{Xt+1}$ follows the AR(1) process, we can simplify the equation as

$$\begin{aligned}\mathbb{E}_{t+1}\left(\frac{X^p_{t+1}}{X_t}\right) &\simeq \frac{r(1+\mu)}{r-\mu}+\frac{r(1+\mu)}{r-\mu}\sum_{j=0}^{\infty}\left(\frac{1+\mu}{1+r}\phi\right)^j\hat{g}_{Xt+1} \\ &= \frac{r(1+\mu)}{r-\mu}+\frac{r(1+\mu)}{r-\mu}\frac{1+r}{1+r-(1+\mu)\phi}\hat{g}_{Xt+1}.\end{aligned}$$

Using the law of iterated expectations, we obtain the first-order approximation of $\Delta\mathbb{E}_{t+1}\left(X^p_{t+1}/X_t\right) = \mathbb{E}_{t+1}\left(X^p_{t+1}/X_t\right) - \mathbb{E}_t\left(X^p_{t+1}/X_t\right)$:

$$\mathbb{E}_t\left(\frac{X^p_{t+1}}{X_t}\right) \simeq \frac{r(1+\mu)}{r-\mu}+\frac{r(1+\mu)}{r-\mu}\frac{1+r}{1+r-(1+\mu)\phi}\phi\hat{g}_{Xt}.$$

Therefore,

$$\begin{aligned}\Delta\mathbb{E}_{t+1}\left(\frac{X^p_{t+1}}{X_t}\right) &= \frac{r(1+\mu)}{r-\mu}\frac{1+r}{1+r-(1+\mu)\phi}\left(\hat{g}_{Xt+1}-\phi\hat{g}_{Xt}\right) \\ &= \frac{r(1+\mu)}{r-\mu}\frac{1+r}{1+r-(1+\mu)\phi}\varepsilon_{t+1}. \qquad (54)\end{aligned}$$

We now substitute (53) and (54) into (52):

$$\Delta c_{t+1} = \omega^*_\mu\Delta c_t + (1-\omega)\frac{r}{r-\mu}\frac{(1+r)(1+\mu)}{1+r-(1+\mu)\phi}\varepsilon_{t+1}, \qquad (55)$$

which proves (27) in the main text. Imposing $\mu=0$ also leads to (18) in the main text.

A.5 Proof of Proposition 4

We first prove the first part of the proposition. From the definition of the first-order autocorrelation, we calculate $\rho_{\Delta c}^{HY\text{-}SI} = Cov\left(\Delta c_{t+1}^{HY}, \Delta c_t^{HY}\right) / Var\left(\Delta c_t^{HY}\right)$. Changes in consumption under the hybrid model are expressed as $\Delta C_{t+1}^{HY} = (1-\lambda)\Delta C_{t+1} + \lambda \Delta X_{t+1}$, which we normalize by X_t to obtain $\Delta c_{t+1}^{HY} = (1-\lambda)\Delta c_{t+1} + \lambda g_{Xt+1}$.

First, $Cov\left(\Delta c_{t+1}^{HY}, \Delta c_t^{HY}\right)$, the numerator of $\rho_{\Delta c}^{HY\text{-}SI}$, is given by

$$\begin{aligned} Cov\left(\Delta c_{t+1}^{HY}, \Delta c_t^{HY}\right) &= (1-\lambda)^2 Cov\left(\Delta c_{t+1}, \Delta c_t\right) + \lambda(1-\lambda) Cov\left(g_{Xt+1}, \Delta c_t\right) \\ &\quad + \lambda(1-\lambda) Cov\left(g_{Xt}, \Delta c_{t+1}\right) + \lambda^2 Cov\left(g_{Xt+1}, g_{Xt}\right). \end{aligned}$$

Because both Δc_t and g_{Xt} follow the AR(1) process (see Lemma 2), $Cov\left(\Delta c_{t+1}, \Delta c_t\right) = \omega^* Var\left(\Delta c_t\right)$, $Cov\left(g_{Xt+1}, \Delta c_t\right) = \phi Cov\left(g_{Xt}, \Delta c_t\right)$, $Cov\left(g_{Xt}, \Delta c_{t+1}\right) = \omega^* Cov\left(g_{Xt}, \Delta c_t\right)$, and $Cov\left(g_{Xt+1}, g_{Xt}\right) = \phi Var\left(g_{Xt}\right)$. Substituting these expressions into the above equation yields

$$\begin{aligned} Cov\left(\Delta c_{t+1}^{HY}, \Delta c_t^{HY}\right) &= \left[(1-\lambda)^2 Var\left(\Delta c_t\right) + \lambda(1-\lambda) Cov\left(g_{Xt}, \Delta c_t\right)\right]\omega^* \\ &\quad + \left[\lambda^2 Var\left(g_{Xt}\right) + \lambda(1-\lambda) Cov\left(g_{Xt}, \Delta c_t\right)\right]\phi. \end{aligned} \tag{56}$$

Next, the variance $Var\left(\Delta c_t^{HY}\right)$, the denominator of $\rho_{\Delta c}^{HY\text{-}SI}$, can similarly be calculated. The resulting expression is

$$\begin{aligned} Var\left(\Delta c_t^{HY}\right) &= (1-\lambda)^2 Var\left(\Delta c_t\right) + 2\lambda(1-\lambda) Cov\left(g_{Xt}, \Delta c_t\right) \\ &\quad + \lambda^2 Var\left(g_{Xt}\right). \end{aligned} \tag{57}$$

Finally, taking the ratio of (56) to (57) yields

$$\begin{aligned} \rho_{\Delta c}^{HY\text{-}SI} &= \frac{(1-\lambda)^2 Var\left(\Delta c_t\right) + \lambda(1-\lambda) Cov\left(g_{Xt}, \Delta c_t\right)}{Var\left(\Delta c_t^{HY}\right)}\omega^* + \frac{\lambda^2 Var\left(g_{Xt}\right) + \lambda(1-\lambda) Cov\left(g_{Xt}, \Delta c_t\right)}{Var\left(\Delta c_t^{HY}\right)}\phi \\ &= (1-\Lambda)\omega^* + \Lambda\phi, \end{aligned} \tag{58}$$

which is (23) in the main text. We note that Λ is a function not only of λ but also of $Var\left(\Delta c_t\right)$, $Cov\left(g_{Xt}, \Delta c_t\right)$, and $Var\left(g_{Xt}\right)$. From (18) and $g_{Xt} = \phi g_{Xt-1} + \varepsilon_t$, these second moments are calculated as

$$Var\left(\Delta c_t\right) = \frac{(1-\omega)^2}{1-(\omega^*)^2}\left(\frac{1+r}{1+r-\phi}\right)^2 \sigma^2 = \Omega^2\left(\frac{1+r}{1+r-\phi}\right)^2 \sigma^2, \tag{59}$$

$$Cov\left(g_{Xt}, \Delta c_t\right) = \frac{1-\omega}{1-\phi\omega^*}\frac{1+r}{1+r-\phi}\sigma^2 = \Omega_\phi \frac{1+r}{1+r-\phi}\sigma^2, \tag{60}$$

$$Var\left(g_{Xt}\right) = \frac{1}{1-\phi^2}\sigma^2, \tag{61}$$

where, as we defined in the proposition, $\Omega = (1-\omega)/\sqrt{1-(\omega^*)^2}$ and $\Omega_\phi = (1-\omega)/(1-\phi\omega^*)$.

We next prove the second part of the proposition. Let us take the ratios of $Var(\Delta c_t)/Var(g_{Xt})$ and $Cov(g_{Xt}, \Delta c_t)/Var(g_{Xt})$. These ratios are given by

$$\begin{aligned}
\frac{Var(\Delta c_t)}{Var(g_{Xt})} &= \Omega^2 \left(\frac{1+r}{1+r-\phi}\right)^2 (1-\phi^2) \\
&= \left(\Omega V_{\Delta c}^{RE}\right)^2, \\
\frac{Cov(g_{Xt}, \Delta c_t)}{Var(g_{Xt})} &= \Omega_\phi \frac{1+r}{1+r-\phi}(1-\phi^2) \\
&= \sqrt{1-\phi^2}\left(\Omega_\phi V_{\Delta c}^{RE}\right),
\end{aligned}$$

where $V_{\Delta c}^{RE} = [(1+r)/(1+r-\phi)]\sqrt{1-\phi^2}$ as shown in Table 2. Using (57) and the above two equations, we have

$$\begin{aligned}
\frac{Var\left(\Delta c_t^{HY}\right)}{Var(g_{Xt})} &= (1-\lambda)^2 \frac{Var(\Delta c_t)}{Var(g_{Xt})} + 2\lambda(1-\lambda)\frac{Cov(g_{Xt}, \Delta c_t)}{Var(g_{Xt})} + \lambda^2 \\
&= (1-\lambda)^2 \left(\Omega V_{\Delta c}^{RE}\right)^2 + 2\lambda(1-\lambda)\sqrt{1-\phi^2}\left(\Omega_\phi V_{\Delta c}^{RE}\right) + \lambda^2.
\end{aligned}$$

Since $V_{\Delta c}^{HY\text{-}SI}$ is the standard deviation ratio of $sd\left(\Delta c_t^{HY}\right)$ to $sd(g_{Xt})$, $V_{\Delta c}^{HY\text{-}SI} = \sqrt{Var\left(\Delta c_t^{HY}\right)/Var(g_{Xt})}$. Therefore, we obtain (27) in the proposition:

$$V_{\Delta c}^{HY\text{-}SI} = \sqrt{(1-\lambda)^2\left(\Omega V_{\Delta c}^{RE}\right)^2 + 2\lambda(1-\lambda)\sqrt{1-\phi^2}\left(\Omega_\phi V_{\Delta c}^{RE}\right) + \lambda^2}.$$

We have two remarks on Proposition 4. First, we can also obtain $V_{\Delta c}^{HY\text{-}RE}$ by evaluating $V_{\Delta c}^{HY\text{-}SI}$ at $\omega = 0$. Since $\Omega = \Omega_\phi = 1$ under $\omega = 0$, we can obtain $V_{\Delta c}^{HY\text{-}RE}$ that appears in Table 2:

$$V_{\Delta c}^{HY\text{-}RE} = \sqrt{(1-\lambda)^2\left(V_{\Delta c}^{RE}\right)^2 + 2\lambda(1-\lambda)\sqrt{1-\phi^2}V_{\Delta c}^{RE} + \lambda^2}.$$

Second, we used the assumption that $\mu = 0$ throughout the proof. For more general expressions under $\mu \neq 0$, we similarly calculate $\rho_{\Delta c}^{HY\text{-}SI}$, using the stochastic process of Δc_{t+1} in Proposition 5.

A.6 Proof of Proposition 5

The derivations of (45) and (55) in the previous sections are applicable to the case of non-zero μ. Therefore, we can derive (26) and (27) directly from (45) and (55), respectively.

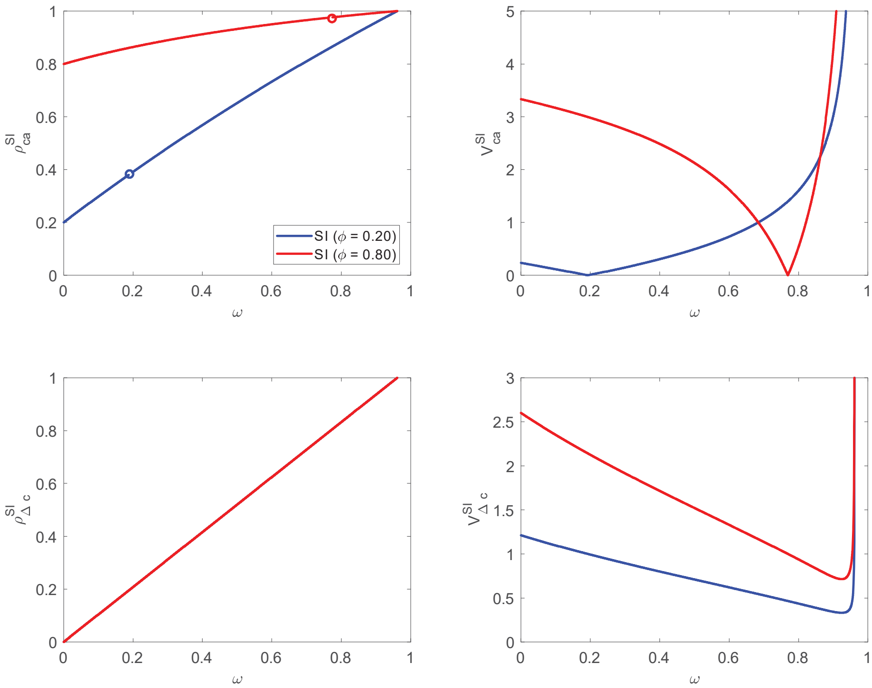

Figure 1: The persistence and volatility of the current account and changes in consumption

Note: The persistence and volatility of ca_t and Δc_t against the degree of information rigidity ω. The upper panels show the persistence and volatility of the current account and the lower panels show those of changes in consumption. In the upper-left panel, each line has a disconnect at $\omega = \phi/(1+r)$ because the current account is independent of ε_t at $\omega = \phi/(1+r)$. In the lower-left panel, the predictions of the SI model are the same between $\phi = 0.20$ and $\phi = 0.80$ because $\rho_{\Delta c}^{SI}$ is independent of ϕ.

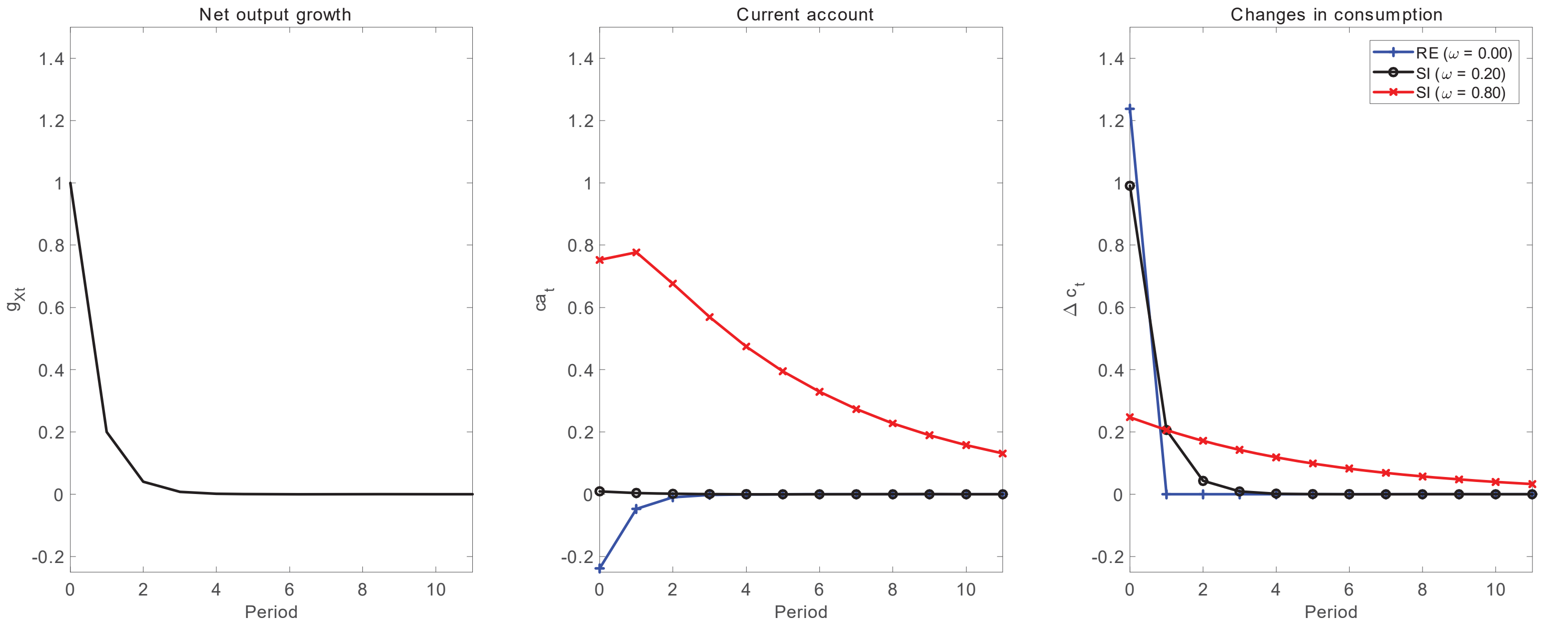

Figure 2: Impulse response function of g_{Xt}, ca_t, and Δc_t

Note: Impulse response functions of the net output growth g_{Xt} (left panel), the current account ca_t (middle panel), and changes in consumption Δc_t (right panel) to a unit increase in ε_t. The stochastic process of net output growth is given by $g_{Xt} = (1 - \phi)\, \mu + \phi g_{Xt-1} + \varepsilon_t$, where $\phi = 0.2$ and $\mu = 0$.

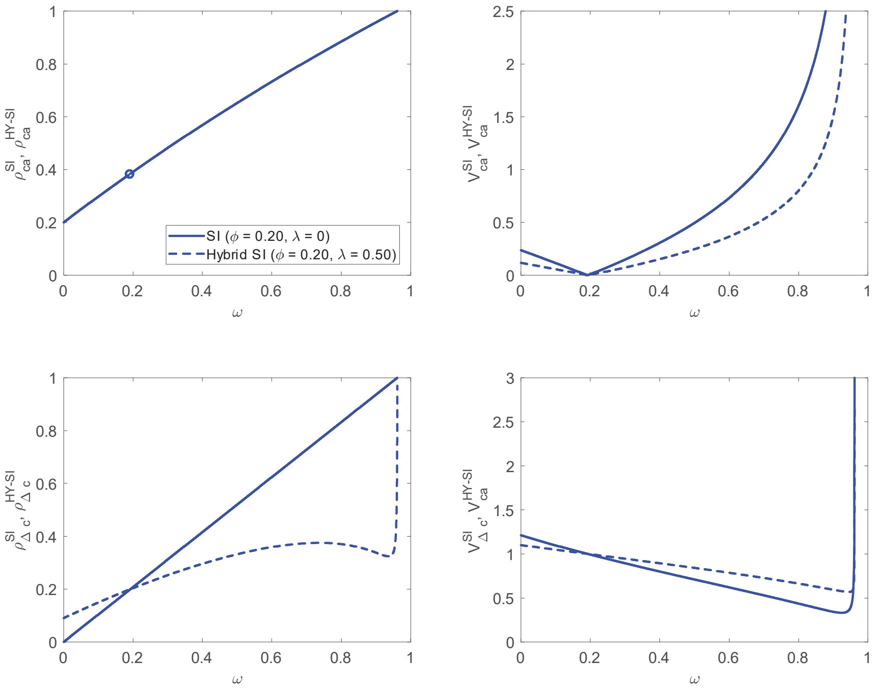

Figure 3: Effects of imperfect capital mobility

Note: The persistence and volatility of ca_t and Δc_t against the degree of information rigidity ω. The solid lines represent the predictions of the SI model while the dashed lines point to the predictions of the hybrid SI model with $\lambda = 0.50$. In the upper-left panel, the predictions of the two models are the same, because $\rho_{ca}^{HY\text{-}SI} = \rho_{ca}^{SI}$.

Table 1: Sample moments of the current account, net output growth, and changes in consumption in rich OECD countries (1980-2013)

	Data
Persistence of current account (ρ_{ca}^{data})	0.82
Volatility of current account (V_{ca}^{data})	2.30
Persistence of net output growth (ϕ^{data})	0.16
Persistence of consumption growth ($\rho_{\Delta c}^{data}$)	0.25
Volatility of consumption growth ($V_{\Delta c}^{data}$)	1.02

Note: Numbers reported are the sample mean of actual moments across 16 OECD countries over 1980-2013. The selected countries include Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Iceland, Italy, Japan, the Netherlands, Norway, Sweden, the UK, and the US. In this table, the current account and changes in consumption are scaled as a percent of the net output.

Table 2: Theoretical predictions of the RE models

	The RE model	The hybrid RE model
Current account		
Persistence	$\rho_{ca}^{RE} = \phi$	$\rho_{ca}^{HY\text{-}RE} = \phi$
Volatility	$V_{ca}^{RE} = \dfrac{\lvert\phi\rvert}{1+r-\phi}$	$V_{ca}^{HY\text{-}RE} = (1-\lambda)V_{ca}^{RE}$
Changes in consumption		
Persistence	$\rho_{\Delta c}^{RE} = 0$	$\rho_{\Delta c}^{HY\text{-}RE} = \Lambda\phi$
Volatility	$V_{\Delta c}^{RE} = \dfrac{1+r}{1+r-\phi}\sqrt{1-\phi^2}$	$V_{\Delta c}^{HY\text{-}RE}$
		$= \sqrt{(1-\lambda)^2 \left(V_{\Delta c}^{RE}\right)^2 + 2\lambda(1-\lambda)\sqrt{1-\phi^2}V_{\Delta c}^{RE} + \lambda^2}$

Note: The theoretical predictions are made under the assumption that g_{Xt} follows the AR(1) process with $\mu = 0$. In the main text, we assess $\phi = \phi^{data} = 0.16$ and $r = 0.04$. In the persistence of changes in consumption, Λ is a function of r, ϕ, and λ, satisfying $0 \leq \Lambda \leq 1$. See Appendix A.5 for the detailed expression for Λ under the hybrid RE model.

Table 3: Predictions of the RE models ($\mu \neq 0$)

	RE model				Hybrid RE model				OECD Data			
	ρ_{ca}^{RE}	V_{ca}^{RE}	$\rho_{\Delta c}^{RE}$	$V_{\Delta c}^{RE}$	$\rho_{ca}^{HY\text{-}RE}$	$V_{ca}^{HY\text{-}RE}$	$\rho_{\Delta c}^{HY\text{-}RE}$	$V_{\Delta c}^{HY\text{-}RE}$	ρ_{ca}^{data}	V_{ca}^{data}	$\rho_{\Delta c}^{data}$	$V_{\Delta c}^{data}$
Australia	0.13	0.25	0.00	2.06	0.13	0.00	0.12	1.01	0.44	1.26	0.16	0.95
Austria	0.03	0.07	0.00	1.97	0.03	0.00	0.03	1.02	0.88	1.89	-0.02	0.82
Belgium	-0.01	0.01	0.00	1.59	-0.01	0.00	-0.01	1.03	0.78	2.50	-0.29	1.11
Canada	0.30	0.61	0.00	1.98	0.30	0.01	0.30	1.01	0.81	1.52	0.39	0.67
Denmark	-0.01	0.02	0.00	1.46	-0.01	0.00	-0.01	1.02	0.94	3.73	0.20	1.21
Finland	0.17	0.37	0.00	2.19	0.17	0.00	0.17	1.01	0.92	2.77	0.34	0.74
France	0.17	0.28	0.00	1.75	0.17	0.00	0.16	1.01	0.93	3.45	0.49	1.01
Germany	0.15	0.36	0.00	2.49	0.15	0.31	0.01	2.27	0.96	2.26	0.11	1.69
Iceland	-0.16	0.23	0.00	1.48	-0.16	0.20	-0.02	1.41	0.71	2.32	0.25	0.91
Italy	0.44	1.10	0.00	2.34	0.44	0.05	0.40	1.05	0.68	1.42	0.34	1.15
Japan	0.17	0.37	0.00	2.21	0.17	0.01	0.16	1.04	0.75	0.89	0.01	0.84
Netherlands	0.20	0.42	0.00	2.12	0.20	0.00	0.20	1.01	0.85	2.07	0.74	0.81
Norway	0.17	0.40	0.00	2.35	0.17	0.00	0.17	1.00	0.84	2.48	0.26	0.76
Sweden	0.05	0.09	0.00	1.83	0.05	0.00	0.05	1.01	0.95	2.96	0.12	0.73
United Kingdom	0.43	1.44	0.00	3.17	0.43	0.04	0.39	1.06	0.91	3.76	0.45	1.44
United States	0.37	1.04	0.00	2.71	0.37	0.24	0.20	1.38	0.76	1.47	0.41	1.43
Mean	0.16	0.44	0.00	2.11	0.16	0.06	0.15	1.15	0.82	2.30	0.25	1.02

Note: The moments of the current account and changes in consumption predicted by the RE model (the left panel), the hybrid RE model (the middle panel), and the actual moments (the right panel). Each panel reports the persistence of the current account (in the first column), the volatility of the current account (in the second column), the persistence of changes in consumption (in the third column), and the volatility of changes in consumption (in the fourth column), respectively. Here, the current account and changes in consumption are scaled by the net output, and the net output growth is assumed to follow the AR(1) process with the mean growth rate μ^{data} and persistence of ϕ^{data}. The mean growth rates of the net output in the data (μ^{data}) are 1.76, 1.86, 1.47, 1.23, 1.26, 1.80, 1.27, 2.10, 1.66, 1.28, 1.81, 1.66, 1.94, 1.66, 2.00, and 1.81 percent in the order of countries shown in the table. The value of ϕ used for the predictions can be confirmed from ρ_{ca}^{RE} in the first column of the left panel because the persistence of the current account is predicted to equal that of the net output growth in the RE models. In the hybrid RE model shown in the middle panel, λ is estimated by the Bayesian minimum distance estimator and the reported moments are evaluated at the posterior mean estimate of λ.

Table 4: Predictions of the SI models ($\mu \neq 0$)

	SI model				Hybrid SI model				OECD Data			
	ρ_{ca}^{SI}	V_{ca}^{SI}	$\rho_{\Delta c}^{SI}$	$V_{\Delta c}^{SI}$	$\rho_{ca}^{HY\text{-}SI}$	$V_{ca}^{HY\text{-}SI}$	$\rho_{\Delta c}^{HY\text{-}SI}$	$V_{\Delta c}^{HY\text{-}SI}$	ρ_{ca}^{data}	V_{ca}^{data}	$\rho_{\Delta c}^{data}$	$V_{\Delta c}^{data}$
Australia	0.67	1.24	0.59	1.07	0.82	1.22	0.43	0.81	0.44	1.26	0.16	0.95
Austria	0.75	2.03	0.74	0.81	0.98	2.03	0.08	0.78	0.88	1.89	-0.02	0.82
Belgium	0.51	0.94	0.52	0.92	1.00	2.65	0.00	0.93	0.78	2.50	-0.29	1.11
Canada	0.85	1.60	0.74	0.83	0.93	1.61	0.51	0.72	0.81	1.52	0.39	0.67
Denmark	0.72	1.49	0.72	0.62	0.87	1.46	0.29	0.59	0.94	3.73	0.20	1.21
Finland	0.83	2.26	0.77	0.85	0.96	2.51	0.32	0.69	0.92	2.77	0.34	0.74
France	0.77	1.38	0.69	0.79	1.00	3.44	0.18	0.87	0.93	3.45	0.49	1.01
Germany	0.68	1.45	0.59	1.29	0.99	2.79	0.17	0.85	0.96	2.26	0.11	1.69
Iceland	0.41	1.09	0.53	0.84	0.93	2.24	0.05	0.55	0.71	2.32	0.25	0.91
Italy	0.87	1.24	0.70	1.05	0.88	1.16	0.67	1.00	0.68	1.42	0.34	1.15
Japan	0.66	1.07	0.55	1.22	0.92	0.96	0.26	0.85	0.75	0.89	0.01	0.84
Netherlands	0.83	2.09	0.76	0.84	0.86	2.03	0.70	0.77	0.85	2.07	0.74	0.81
Norway	0.85	2.67	0.79	0.86	0.97	2.48	0.28	0.73	0.84	2.48	0.26	0.76
Sweden	0.77	1.94	0.75	0.74	0.98	2.93	0.11	0.71	0.95	2.96	0.12	0.73
United Kingdom	0.88	2.07	0.73	1.32	0.88	1.44	0.66	1.19	0.91	3.76	0.45	1.44
United States	0.82	1.31	0.65	1.30	0.83	1.26	0.64	1.24	0.76	1.47	0.41	1.43
Mean	0.74	1.62	0.68	0.96	0.93	2.01	0.33	0.83	0.82	2.30	0.25	1.02

Note: The moments of the current account and changes in consumption predicted by the SI model (the left panel), the hybrid SI model (the middle panel), and the actual moments (the right panel). In both models, the parameters are obtained by the Bayesian minimum distance estimator, and the reported moments are evaluated at the posterior mean estimates of ω and/or λ. We impose the assumption of $\lambda = 0$ for the SI model. The right panel reproduces the right panel of Table 3 to facilitate comparisons between the models and data. See the footnote of Table 3 for the other details.

Table 5: Estimates of ω and λ

	Hybrid RE model		SI model		Hybrid SI model			
	λ	95% CI	ω	95% CI	ω	95% CI	λ	95% CI
Australia	0.99	[0.98, 0.99]	0.58	[0.57, 0.59]	0.76	[0.73, 0.79]	0.46	[0.41, 0.52]
Austria	0.98	[0.97, 0.99]	0.72	[0.71, 0.74]	0.95	[0.95, 0.96]	0.75	[0.72, 0.78]
Belgium	0.95	[0.93, 0.97]	0.51	[0.49, 0.53]	0.97	[0.97, 0.98]	0.92	[0.89, 0.95]
Canada	0.99	[0.98, 0.99]	0.72	[0.71, 0.72]	0.86	[0.84, 0.87]	0.49	[0.45, 0.54]
Denmark	0.95	[0.93, 0.97]	0.71	[0.68, 0.73]	0.85	[0.83, 0.87]	0.42	[0.38, 0.45]
Finland	0.994	[0.991, 0.997]	0.75	[0.74, 0.76]	0.93	[0.91, 0.94]	0.58	[0.54, 0.61]
France	0.98	[0.98, 0.99]	0.67	[0.66, 0.68]	0.97	[0.97, 0.98]	0.86	[0.80, 0.91]
Germany	0.15	[0.10, 0.20]	0.58	[0.56, 0.61]	0.97	[0.97, 0.98]	0.84	[0.78, 0.89]
Iceland	0.15	[0.10, 0.20]	0.52	[0.48, 0.56]	0.92	[0.92, 0.93]	0.47	[0.43, 0.51]
Italy	0.96	[0.94, 0.97]	0.68	[0.67, 0.69]	0.70	[0.69, 0.71]	0.17	[0.11, 0.24]
Japan	0.97	[0.95, 0.98]	0.54	[0.53, 0.55]	0.87	[0.84, 0.89]	0.75	[0.72, 0.79]
Netherlands	0.995	[0.992, 0.997]	0.74	[0.74, 0.75]	0.78	[0.77, 0.80]	0.16	[0.11, 0.21]
Norway	0.998	[0.997, 0.999]	0.78	[0.77, 0.78]	0.94	[0.92, 0.95]	0.65	[0.60, 0.70]
Sweden	0.99	[0.98, 0.99]	0.73	[0.72, 0.75]	0.96	[0.96, 0.96]	0.68	[0.65, 0.70]
United Kingdom	0.97	[0.96, 0.98]	0.72	[0.71, 0.73]	0.72	[0.70, 0.73]	0.31	[0.23, 0.39]
United States	0.76	[0.73, 0.79]	0.63	[0.62, 0.64]	0.65	[0.63, 0.66]	0.10	[0.06, 0.14]
Mean	0.86	-	0.66	-	0.86	-	0.54	-

Note: Each panel reports the posterior mean of the estimated ω and λ along with the 95% credible intervals of the posterior distribution.

Table 6: Estimates of the quasi-marginal likelihood

	Hybrid RE model		SI model		Hybrid SI model	
	Geweke	CJ	Geweke	CJ	Geweke	CJ
Australia	-1484.59	-1483.05	-263.00	-263.01	-235.22	-233.32
Austria	-944.99	-942.90	-310.39	-310.40	-44.38	-42.61
Belgium	-1247.42	-1245.71	-778.25	-778.25	-207.57	-205.99
Canada	-1020.59	-1019.03	-123.49	-123.49	-46.19	-44.33
Denmark	-1522.23	-1520.55	-358.00	-358.00	-204.87	-203.07
Finland	-1565.05	-1563.49	-120.21	-120.22	-25.18	-23.30
France	-1613.40	-1611.82	-260.53	-260.53	-149.01	-147.10
Germany	-998.86	-997.27	-354.85	-354.84	-84.18	-82.10
Iceland	-716.11	-714.54	-367.65	-367.65	-130.78	-128.99
Italy	-346.46	-344.84	-108.66	-108.66	-121.95	-120.28
Japan	-1005.82	-1004.19	-275.41	-275.42	-82.51	-80.66
Netherlands	-1504.21	-1502.68	-6.96	-6.96	-17.19	-15.36
Norway	-2059.11	-2057.55	-217.14	-217.14	-53.79	-51.94
Sweden	-2256.33	-2254.76	-491.05	-491.05	-31.00	-29.14
United Kingdom	-471.03	-469.40	-116.49	-116.48	-112.78	-112.14
United States	-312.78	-311.20	-80.34	-80.35	-102.59	-101.23

Note: Each panel reports the quasi-marginal likelihood (QML) estimates. The left panel, the middle panel, and the right panel report the QML for the hybrid RE model, the SI model, and the hybrid SI model, respectively. Each panel reports the QMLs obtained by the modified harmonic mean estimator of Geweke (1999) (denoted by Geweke) and those obtained by Chib and Jeliazkov's (2001) estimator (denoted by CJ).