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By: Jesus Felipe*
Scott Fullwiler**
Al-Habbyel Yusoph***

**Asian Development Bank;*
*De La Salle University*
***University of Missouri-Kansas*
****University of the Philippines*

**DLSU - Angelo King Institute**
**for Economic and Business Studies**

Room 223, St. La Salle Hall
2401 Taft Avenue, Manila, 0922, Philippines

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# Why the Feldstein-Horioka "Puzzle" Remains Unsolved

Jesus Felipe (*)
Scott Fullwiler (**)
Al-Habbyel Yusoph (***)

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**Abstract**

This paper argues that the 40-year-old Feldstein-Horioka "puzzle" (i.e., in a regression of the domestic investment rate on the domestic saving rate, the estimated coefficient is significantly larger than expected in a world with high capital mobility) should have never been labeled as such. First, we show that the series of investments and savings typically used in empirical exercises to test the Feldstein-Horioka thesis are not appropriate for testing capital mobility. Second, and complementary to the first point, we show that the Feldstein-Horioka regression is not a model in the econometric sense, that is, an equation with a proper error term (a random variable). The reason is that by adding the capital account to their regression, one gets the accounting identity that relates the capital account, domestic investment, and domestic saving. This implies that the estimate of the coefficient of the saving rate in the Feldstein-Horioka regression can be thought of as a biased estimate of the same coefficient in the accounting identity, where it has a value of 1. Because the omitted variable is known, we call it *pseudo bias*. Given that this (pseudo) bias is known to be negative and less than 1 in absolute terms, it should come as no surprise that the Feldstein-Horioka regression yields a coefficient between 0 and 1

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*Keywords:* accounting identity, Feldstein-Horioka paradox (puzzle), investment, pseudo bias, saving

(*) Economic Research and Regional Cooperation Department, Asian Development Bank, and School of Economics, De La Salle University, Philippines. Corresponding author: jesus.felipe@dlsu.edu.ph; (**) University of Missouri-Kansas City: scottf@umkc.edu; (***) University of the Philippines: alyusoph@up.edu.ph. This paper reflects the views of the authors solely. We are grateful to Taiji Furusawa, Shigeyuki Hamori, Shigeto Kitano, Kevin Nell, Yasuyuki Sawada, Kenichi Ueda, Nobuyoshi Yamori, and participants at the Seminars at Kobe University and the University of Tokyo for their comments and suggestions. We are particularly grateful to Charles Horioka for discussions and invaluable insights into the history of the puzzle. Any errors are solely ours.

The Feldstein and Horioka (1980) "puzzle" (FHP hereafter) was referred to as one of the most significant and enduring anomalies in international macroeconomics by Obstfeld and Rogoff (2001). The anomaly or puzzle remains until today, as one of the two authors recently proposed a solution to it (Ford & Horioka, 2017).

Under conditions of perfect capital mobility, economic theory suggests that financial capital flows move across borders to seek the highest returns, equalizing real interest rates across countries. Feldstein and Horioka (1980) formalized this hypothesis and suggested using the saving-investment correlation to measure (lack of) capital market integration. They proposed testing it by estimating the following regression:

$$I_t = \alpha^* + \beta^* S_t + u_t, \qquad (1)$$

where $I$ is gross domestic investment and $S$ is gross domestic saving, both as a percent of nominal GDP, and $u$ is an error term. The Feldstein and Horioka test was initially proposed as a test of world capital market integration, that is, as a measure of the degree of capital mobility across countries. If financial capital seeks the highest international returns, Feldstein and Horioka (1980) argued that $\beta^*$ (referred to as the "retention coefficient") should be close to zero (though not necessarily zero) and certainly below one, that is, $0 < \beta^* < 1$.[1] Equation (1) was estimated with data for 16 OECD countries during 1960–1974. Although the relationship in equation (1) has often been referred to in the literature as a *correlation* (for obvious reasons), in reality, equation (1) is thought of as a model. This is obvious in discussions in the literature about the need to use instrumental variable estimation, error correction models, or the need to add additional regressors.

To their surprise, and this is the puzzle, $\beta^*$ was close to one, which they interpreted as evidence that most savings was retained by the home country, with the average for all countries together being 0.89 in their base equation, and with a standard error of 0.07 (Feldstein & Horioka, 1980, p. 321). They obtained similar results quantitatively and qualitatively from estimating variations on equation (1) that attempted to control for openness, size, economic growth, population age, and so forth. This result was reconfirmed by Feldstein (1983). The standard interpretation of these results in the FHP literature is that domestic investment spending is financed mostly by domestic savings, with little financing from mobile international capital. The FHP is thus concerned with why domestic investment and domestic saving are correlated across countries, especially in a world in which international financial markets very clearly move large amounts of financial capital between countries very rapidly every day.

In this paper, we argue that referring to the Feldstein and Horioka findings as a "puzzle" was misleading, as their work and much of the work that has followed it during the last 40 years suffer from two problems that invalidate it. One concerns the nature of the series used, and the other one the regression itself. These two considerations do not undermine the relevance of the question they posed. The point of the paper is that much of the empirical work undertaken during the past four

[1] More precisely, perfect capital mobility results in variations in the proportion of investment financed by domestic saving relative to international saving as capital flows react quickly to changes in relative returns, raising coefficient standard errors enough to not reject the null hypothesis that $\beta^*$=0.

decades is flawed and, consequently, the question about the degree of capital mobility across countries remains unanswered.

Equation (1) has been the most widely used framework to test the Feldstein-Horioka hypothesis. Within this framework, some authors have nevertheless found that the Feldstein and Horioka hypothesis appears corroborated (i.e., a low or insignificant correlation between saving and investment rates) for some countries or specific time periods (e.g., Tesar, 1991; Sinha & Sinha, 2004; Giannone & Lenza, 2008; Dzhumashev & Cooray, 2016). Some studies using intranational regional data have also found that the null hypothesis in equation (1) cannot be rejected (e.g., Hashiguchi & Hamori, 2009; Yamori, 1995; Boyreau-Debray & Wei, 2004). This would seem to corroborate Frankel's (1992) arguments about the need to use data free of currency premium to test Feldstein and Horioka's (1980) thesis. Yet, Apergis and Tsoumas (2009, p. 73) concluded: "…the majority of the aforementioned studies support a strong correlation between [domestic] savings and investment, albeit lower than that displayed in the earlier attempts," and, though important disagreements on appropriate tests of capital mobility remain, "the majority of the results do not clearly validate the capital mobility hypothesis."

Perhaps, for this reason, some authors opted to follow a different methodology to examine the puzzle. Instead of directly testing equation (1), they constructed RBC models or DSGE models (e.g., Mendoza, 1991; Bai & Zhang, 2010; Chang & Smith, 2014). Indeed, one can construct models and parameterize them to show that the correlation between savings and investment is low. The question is whether these exercises are true tests of the original hypothesis or, rather, examples of artificially constructed economies that, under some parameter values, generate a low or high (depending on the values) correlation between saving and investment.

Other approaches to test the international capital mobility hypothesis have been proposed. These are based on covered and uncovered interest parity (Frankel, 1992). In these approaches, economic models and econometric tests look at differences in rates of returns (e.g., real interest rates) across countries instead of estimating saving-investment correlations. Frankel (1991) argued that if the goal is to test the degree of integration of capital markets rather than the extent to which domestic savings have crowded out investments, then it is better to look at rates of returns differentials. The broadest test looks at the mean and variability of real interest rates differential, $r - r^*$, where $r$ is the domestic real interest rate and $r^*$ is the world's interest rate. Other tests look at the stationarity and possible co-integration of these differentials. The real rate differential can also be further decomposed to account for country and currency premiums. Frankel (1991) found that despite the equalization of covered interest rates, real interest rate differentials remain amidst the worldwide trend of financial integration.

This paper argues that there are two serious shortcomings with tests of the Feldstein-Horioka hypothesis, in particular (but not only) through equation (1) and variations of it. Together, they raise serious doubts about this literature, both conceptually and empirically. First, Section 2 shows that saving, investment, and *net* financial flows data, as usually defined and measured in the national accounts and used to estimate equation (1), are not appropriate for testing the Feldstein-Horioka hypothesis and capital mobility. Empirical tests of capital mobility in the Feldstein and Horioka literature inherently depend on how (and if) the transactions under consideration appear in official accounts. We show that a test of the Feldstein-Horioka hypothesis based on equation (1) has the accounting wrong. Although some authors critiqued Feldstein and Horioka's approach to testing capital mobility, most did it via econometric methods (e.g., Telatar et al., 2007). Others, like Ford and Horioka (2017), argued that rigidities in goods and services trade explain the FHP, not limitations on capital mobility. Yet, with only a few exceptions (e.g., Borio & Disyatat, 2010, 2015; Shin, 2012), none grounded the analysis in how the relevant transactions are recorded in national accounting.

Second, we argue in Section 3 that there is an additional serious shortcoming with equation (1) and variations of it. This equation can be interpreted as a special case of the national income accounting identity that relates domestic investment, domestic saving, and the capital account (hereafter, $KA$, assumed to include the standard statistical discrepancy), that is,

$$I_t \equiv S_t + KA_t \tag{2}$$

but with $KA_t$ omitted. The symbol $\equiv$ indicates that equation (2) is an accounting identity by construction. The identity of equation (2) is obviously correct. The argument is that the identity poses a serious problem for the interpretation of $\beta^*$ in equation (1). We show that $\beta^*$ obtained in equation (1) is a biased estimate of the corresponding coefficient in the identity as a result of the omission of the capital account. Yet, because the omitted variable is known to the researcher, we refer to it as *pseudo bias*. Economists familiar with these variables would generally expect $\beta^*$to be similar to (most) authors' findings in the literature, that is, in general, larger than zero and less than one. Although Feldstein and Horioka were obviously aware of equation (2) (as most of the profession), they did not see the implications for running a regression of equation (1) in that it is not a true regression model. Although it is true that one does not know a priori the precise value of $\beta^*$, we show that it will fall within the range $0 < \beta^* < 1$ as a consequence of the identity. The problem discussed has no econometric solution. Section 4 provides empirical evidence.

Section 5 concludes that the Feldstein and Horioka argument is a hypothesis waiting to be properly tested. The Appendix elaborates further on the discussion in Section 4 by explicitly considering the statistical discrepancy in the capital account.

## The Solution to the Feldstein-Horioka Puzzle is Not Found in Official Saving, Investment, and Capital Account Balance Data in National Income Accounts

The econometrics of estimating equation (1) implies an equilibrium where saving finances investment and (in the case of alternatives such as ECMs) an adjustment process to a steady-state. The concern here is with the accounting behind the series used: if from equation (2) and using the national income accounts, gross national saving, and the capital account are something other than accounting records of financing of gross domestic investment, then tests of equation (1) and its variants are irrelevant for purposes of the Feldstein-Horioka hypothesis. More generally, although accounting is quite obviously not an economic theory, testing an economic theory requires consistency between the transactions the theory describes and the accounting underlying the transactions recorded in the real-world data investigators base the test upon.

The analysis here agrees with those of Borio and Disyatat (2010, 2015) and Shin (2012), who argued that saving and the capital account balance in the national income accounts are unrelated to accounting records of the financing of investment spending. Saving from the national income accounts is not a record of financing (Borio & Disyatat, 2010, p. 199) but rather the difference between income and spending, both private and government.[2] Although most economists argue that saving finances investment, at least in the long run, even if correct as a matter of causation, the accounting record of saving and investment will not show this. They likewise argued that "by construction, current accounts and net capital flows reveal little about financing. They capture changes in net claims on a country from trade arising in *real* goods and services" but "leave out trade in *financial* assets, which make up the bulk of cross-border financial activity" (p. 199; emphasis in original). We illustrate their points below through a series of examples.

Perhaps what the best economists can do is to follow Shin's (2012) example based on U.S. Flow of Funds accounts and Bank for International Settlements banking statistics data. Shin showed that European banks held large amounts of U.S. mortgage-backed securities and other structured claims on U.S. borrowers in the 2000s; he then also confirmed that the U.S. subsidiaries of those banks funded the purchases via borrowings in wholesale U.S. funding markets and then "shipped" the funds to their home offices. Shin relied on gross flows, not the net flows recorded, as the current account and capital account balances because "to the extent that the banking sector plays an important role in influencing credit conditions, it is gross flows rather than net flows" that are relevant (Shin, 2012, p. 157). In contrast to the "savings glut" view (e.g., Bernanke, 2005), Shin showed that these European banks were not funding the U.S. housing bubble with "excess savings" from Europe.

Nevertheless, and unfortunately, the data for the question that equation (1) attempts to answer do not exist. The closest approximation would be cross-border changes to claims on businesses (debt and equity) and household mortgages (mortgages and mortgage-backed securities because purchases of new homes are part of gross private domestic investment) for domestic private sectors and similar for government-issued liabilities. Even this is inadequate because (currently, at least) it does not account for primary versus secondary market purchases, financing of new homes versus "used" homes, and so forth. Such data would need to record flows for specific loans, securities, and other financial assets, all newly created or issued. However, even this is inadequate (e.g., newly created liabilities, refinance outstanding debt, finance equity repurchases, and so forth, rather than fixed capital spending). Shin (2012) noted similar data difficulties and added that "remedying the data gaps would be an important first step in shedding light on shifting global financial conditions" (p. 173).

Table 1 provides seven examples of transactions, each involving some combination of a domestic bank (U.S. Bank), a firm producing consumption goods (C Firm), a firm producing capital goods (K Firm), members of a household (HH) employed by C Firm, a foreign bank (For Bank), and a foreign firm that both produces and purchases capital goods (For Firm). The examples show that neither domestically sourced nor internationally sourced financing is a transaction that involves spending or a change in income for any parties involved. This means that savings, as defined in the national income accounts, cannot be the accounting record of domestically-sourced financing of investment spending. Likewise, it also means that the capital account, as defined in national income accounts, cannot be the accounting record of internationally-sourced financing of investment spending.

**Example 1—The household receives wages and saves by stashing cash in a mattress.** In the T-accounts to accompany this example, C Firm pays wages to a member of HH, who decides to stash the cash in a mattress rather than consuming more. These are obviously two separate transactions. For the first (top row of entries), assuming that both keep accounts at a U.S. Bank, this

[2] Some saving measures in national income accounts incorporate imputations of durable goods and capital consumption, of course, but this is also quite obviously not part of the accounting record of financing investment flows.

is a simple exchange of U.S. Bank's deposits (liabilities of U.S. Bank) from the employer's account to the employee's account ($-D_{CF}$ and $+D_{HH}$ ). In C Firm's T-account, this is a reduction in deposits and also in its equity ($-Eq_{CF}$) because wages are a cost that reduces profits and thus retained earnings, ceteris paribus, whereas for HH this is an increase in both ($-Eq_{HH}$). For the second transaction, HH withdraws the full amount ($-D_{HH}$) as cash ($-C_{USB}$ and $+C_{HH}$).

**Table 1**

*Examples of Transactions Between Various Sectors*

| U.S. Bank | | C Firm | | K Firm | | HH | | For Bank | | For Firm | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A | L/E | A | L/E | A | L/E | A | L/E | A | L/E | A | L/E |
| **Example 1—The household receives wages and saves by stashing cash in a mattress.** | | | | | | | | | | | |
| | $-D_{CF}$<br>$+D_{HH}$ | $-D_{CF}$ | $-Eq_{CF}$ | | | $+D_{HH}$ | $+Eq_{HH}$ | | | | |
| $-C_{USB}$ | $-D_{HH}$ | | | | | $-D_{HH}$<br>$+C_{HH}$ | | | | | |
| **Example 2—The household purchases a corporate bond from the consumption goods firm, issued to purchase capital goods from the capital goods firm.** | | | | | | | | | | | |
| | $-D_{HH}$<br>$+D_{CF}$ | $+D_{CF}$ | $+B_{CF}$ | | | $-D_{HH}$<br>$+B_{CF}$ | | | | | |
| | $-D_{CF}$<br>$+D_{KF}$ | $-D_{CF}$<br>$+K_{CF}$ | | $+D_{KF}$<br>$-K_{KF}$ | | | | | | | |
| **Example 3—The consumption goods firm issues a corporate bond to the foreign bank to finance the capital purchase from the capital goods firm.** | | | | | | | | | | | |
| | $-D_{FB}$<br>$+D_{CF}$ | $+D_{CF}$ | $+B_{CF}$ | | | | | $+B_{CF}$<br>$-D_{FB}$ | | | |
| | $-D_{CF}$<br>$+D_{KF}$ | $-D_{CF}$<br>$+K_{CF}$ | | $+D_{KF}$<br>$-K_{KF}$ | | | | | | | |
| **Example 4—The household purchases a corporate bond newly issued by the foreign firm; the foreign firm is refinancing a maturing loan from the foreign bank.** | | | | | | | | | | | |
| | $-D_{HH}$<br>$+D_{FB}$ | | | | | $-D_{HH}$<br>$+B_{FF}$ | | $+D_{FB}$ | $+D_{FF}$ | $+D_{FF}$ | $+B_{FF}$ |
| | | | | | | | | $-L_{FF}$ | $-D_{FF}$ | $-D_{FF}$ | $-L_{FF}$ |
| **Example 5—The foreign firm uses its own deposits to purchase capital goods from the capital goods firm in the U.S.** | | | | | | | | | | | |
| | $-D_{FB}$<br>$+D_{KF}$ | | | $+D_{KF}$<br>$-K_{KF}$ | | | | $-D_{FB}$ | $-D_{FF}$ | $+K_{FF}$<br>$-D_{FF}$ | |
| **Example 6—The consumption goods firm issues a corporate bond to the household in order to purchase capital goods from the foreign firm.** | | | | | | | | | | | |
| | $-D_{HH}$<br>$+D_{CF}$ | $+D_{CF}$ | $+B_{CF}$ | | | $-D_{HH}$<br>$+B_{CF}$ | | | | | |
| | $-D_{CF}$<br>$+D_{FB}$ | $-D_{CF}$<br>$+K_{CF}$ | | | | | | $+D_{FB}$ | $+D_{FF}$ | $+D_{FF}$<br>$-K_{FF}$ | |
| **Example 7—The household purchases the foreign firm's corporate bond, issued to finance a purchase from the capital goods firm.** | | | | | | | | | | | |
| | $-D_{HH}$<br>$+D_{FB}$ | | | | | $-D_{HH}$<br>$+B_{FF}$ | | $+D_{FB}$ | $+D_{FF}$ | $+D_{FF}$ | $+B_{FF}$ |
| | $-D_{FB}$<br>$+D_{KF}$ | | | $+D_{KF}$<br>$-K_{KF}$ | | | | $-D_{FB}$ | $-D_{FF}$ | $-D_{FF}$<br>$+K_{KF}$ | |

Source: Authors

For national accounts, it is the first transaction that is an increase in HH's savings—and also an offsetting reduction in C Firm's savings—not the second transaction because HH receives income but does not raise spending. HH's increased saving is thus a residual of its increased income, not a financing transaction. In the second transaction, the household stuffs the currency in the mattress, which is obviously not the accounting record of financing investment. Instead, it is the allocation of its new savings. [3]

**Example 2—The household purchases a corporate bond from the consumption goods firm, issued to purchase capital goods from the capital goods firm.** Here HH purchases a corporate bond from C Firm ($+B_{CF}$, top transaction). C Firm then purchases capital goods ($+K_{CF}$) from K Firm (bottom transaction). Like the second transaction in Example 1, the top transaction is a reallocation of HH's savings, in this case, from deposits to the bond. The second transaction, however, is both a rise in investment spending by C Firm and a rise in saving by K Firm (ceteris paribus).

Note that HH's lending and C Firm's borrowing in the top transaction do not affect saving in the national income accounts because lending and borrowing transactions are neither spending nor exchanges of income. Saving is a residual of income inflows not matched by spending or other transfer payment outflows that raises the payee's income directly—a change in one's saving thus requires a change in one of those. The accounting record for lending and borrowing changes none of them. Consequently, borrowing and spending are separate transactions in terms of their respective accounting; lending and saving are also similarly separate accounting transactions. This means that saving and investment data are inapplicable to a test of how much domestic investment is financed domestically because "financed domestically" is not what "domestic saving" in the national income accounts actually measures.

As the identity in equation (2) shows, gross domestic saving is not equal to gross domestic investment whenever the capital account balance is non-zero. The examples below incorporate accounting of international capital flows to illustrate when the capital account balance does and does not change.

**Example 3—The consumption goods firm issues a bond to the foreign bank to finance the capital purchase.** This example assumes C Firm issues the bond to For Bank to finance the capital goods purchase. In the first transaction, For Bank uses a deposit ($-D_{FB}$) at a U.S. Bank to purchase the bond from C Firm. This is the sort of mobility of international capital Feldstein and Horioka were attempting to uncover through the estimation of equation (1). In the second transaction, as in Example 2, C Firm purchases the capital goods from K Firm. Once again, according to the national income accounts, only in the second transaction is there a rise in saving. In other words, it is an increase in gross domestic savings, not foreign savings, that accompanies the investment spending in national accounts. There is no net change to For Bank's total claims on U.S. entities and thus no net financial flow recorded from For Bank.

Together, Examples 2 and 3 present the two scenarios that regressions of equation (1) attempt to distinguish—domestic capital investment spending financed domestically in Example 2, or financed via internationally-mobile capital inflows in Example 3. The crucial takeaway is that in both examples,

[3] Note the distinction between saving (without an 's') and savings (with an 's'). Saving is a residual from income flows. Savings is a stock of assets, as in a 'savings account.' Many in the FHP literature instead appear to use the terms interchangeably, perhaps unsurprisingly so given the lack of explicit description of the accounting for transactions under consideration.

it is domestic saving that increases in the national income accounts—the national income accounting data used to estimate equation (1) is unrelated to the issue of whether financing originates domestically or internationally. This illustrates Shin's (2012) claim that the accounting record of international capital mobility, to the degree it is even available, is in the gross changes to specific financial assets held by investors in other countries, not net financial flows that are represented by the capital account balance.[4]

**Example 4—The household purchases a bond newly issued by the foreign firm; the foreign firm is refinancing a maturing loan from a foreign bank**. Here HH now purchases For Firm's bond ($+B_{FF}$) in the first transaction, and For Firm uses the proceeds to pay down a maturing loan at For Bank ($-L_{FF}$) in the second transaction. The national income accounts record no changes in saving or in the capital account balance of either nation because there is neither spending nor changes in incomes of those involved.[5] This example illustrates that purely financial transactions across national borders do not change net positions recorded in the current and capital account balances.

**Example 5—The foreign firm uses its own deposits to purchase capital goods from the capital goods firm in the United States**. In this example's sole transaction, For Bank debits For Firm's deposits $(-D_{FF})$ that pay for the capital goods ($+K_{FF}$). In turn, U.S. Bank credits K Firm's deposits $(+D_{KF})$. To settle the payment among the banks, For Bank's account at U.S. Bank is debited $(-D_{FB})$ (equivalently for net capital flows accounting, the example could have credited US Bank's account at For Bank instead).

Of main importance here is that even though For Firm required no external finance (domestic or foreign) for its purchase of capital goods, the national income accounts record a net increase in the U.S. current account and thus a net increase in For Firm's country's capital account. That is, the national accounts record this transaction as if the U.S. Bank financed For Firm's purchase because it is the decline in For Bank's account at U.S. Bank that raises the difference for the latter between holdings of foreign assets and its foreign liabilities.

**Example 6—The consumption goods firm issues a corporate bond to the household in order to purchase capital goods from the foreign firm.** The first transaction here is identical to the first transaction in Example 2. The second transaction is nearly the reverse of Example 5, with C Firm's purchase of fixed capital produced by For Firm settled among U.S. Bank and For Bank via an increase in For Bank's deposits at U.S. Bank $(+D_{FB})$. This Example presents domestic investment spending financed domestically. However, the national income accounts record a capital inflow as For Bank's acquires deposits at U.S. Bank with no change in foreign-held liabilities of For Bank or For Firm.

Through the lens of equation (1), both Examples 5 and 6 appear as increases in capital mobility to finance investment, the former as U.S. capital outflows to For Firm, and the latter as the opposite. The reality is that both were financed domestically, with Example 5 being For Firm financing its own purchase.

**Example 7—The household purchases the foreign firm's commercial paper, issued to finance a purchase from the capital goods firm** HH's purchase of For Firm's corporate bond

[4] Borio and Disyatat (2010) also make this point.

[5] The caveat here is if For Firm's loan payment contains within it an interest payment because the latter would reduce For Firm's saving and raise For Bank's saving, ceteris paribus.

debits the former's deposits at U.S. Bank and credits For Bank's account (also at US Bank), which credits For Firm's deposits (For Bank's liability, likely in domestic currency).

Here, again, it is only For Firm's imports from K Firm (the bottom transaction) that is a net financial flow across borders in national income accounts. The true financing of For Firm's import purchase is not a net financial flow, illustrating again how the capital mobility at the FHP's core is not recorded in the data FH and others used to estimate equation (1). As noted above, data specifically linking gross capital flows to primary market purchases of securities for the specific purpose of fixed capital spending—rather than refinancing previous debts, for instance—simply do not exist, but these are the data that would be necessary to test the FHP.

Together, the examples show that determining whether capital is mobile (as in Examples 3, 4, and 7) and whether mobile capital actually finances fixed capital purchases (as in Examples 3, 5, 6, and 7) requires gross capital flow data at a level of detail that does not exist in national accounts data. Meanwhile, the saving and net capital flows in the capital account balance data from the national income accounting identity in equation (2) that is the underlying estimation of equation (1) by Feldstein and Horioka, and the FHP literature in general, get the source of finance wrong, repeatedly:

- Example 3 presents gross domestic investment financed by mobile capital, yet the national income accounts record it as a rise in domestic saving; that is, the national income accounts cannot distinguish Example 3 from Example 2 (gross domestic investment financed domestically), a point whose significance cannot be overstated here given that the purpose of estimating equation (1) is to make this exact distinction;
- Example 5 presents a foreign firm financing its own capital goods purchase, yet the national income accounts record it as a rise in the capital account, not saving, of the foreign firm's country because the capital goods were imports; in other words, the national income accounts cannot distinguish this example from Example 7, which is the same capital goods import by For Firm instead financed by US investors;
- Example 6 presents a domestic investor financing imported capital goods financed by a domestic firm, which the national income accounts record as a rise in imports financed by international capital, and thus a rise in the capital account; to the national income accounts, domestic finance of imports in Example 6 is identical to both the self-financed purchase of imported capital goods in Example 5 and foreign finance of imports as in Example 7 (with the countries reversed).

The problems inherent in the depiction of international capital flows within equation (1) were also recognized by Ford and Horioka (2017), who wrote that "global financial markets cannot, by themselves, achieve net transfers of capital" (p. 95). Via multiple anecdotal examples, they argued that frictions in the international trade of goods and services, rather than barriers to international capital mobility, explain the FHP. This concurs with earlier research by Obstfeld and Rogoff (2001) and Eaton et al. (2016), all of whom argued that the true solution to the FHP is a "real" one. As Ford and Horioka (2017) put it, rapid net transfers of financial capital between countries require the absence of frictions in goods markets (p. 95).

Although technically true, this "real" solution is tautological: if the FHP appears to arise from rigidities in goods and services trade, it is because goods and services transactions (and international income transfers in the current account balance) are the only recorded transactions underlying estimation of equation (1). As a general matter of accounting illustrated in Example 4 and also in the first transactions for Examples 2, 3, 6, and 7, national income accounts do not record financing transactions as changes to saving or the capital account balance. The "real" solution envisions scenarios in which international capital mobility becomes more directly connected to trade. However, as demonstrated, the national income accounts by design do not record where financing originated and are thus unable to differentiate Examples 2 vs. 3, Examples 5 vs. 6, Examples 6 vs. 7, and Examples 5 vs. 7. Freeing international trade might change the current account balances of some or even many nations, but the accounting record of this is unrelated to the relative size of domestic versus international financing of a nation's investment spending.

It is important to reiterate here that the analysis in this section in no way suggests that the Feldstein-Horioka hypothesis is intrinsically wrong or a figment of the data. Rather, we argue that the standard national income accounts data frequently used in regressions like equation (1) are inapplicable to a test of the Feldstein-Horioka hypothesis. The following section takes the next logical step and considers what those regressions on equation (1) actually do if they are not a test of the Feldstein-Horioka hypothesis.

### Rationalizing the Estimates of the Feldstein-Horioka Regression

The previous section argued that the series used to test the FH hypothesis (i.e., saving and investment from the national accounts) do not reflect what the hypothesis is about. The series is obviously correct, but it should not be used to test the Feldstein-Horioka hypothesis. This section argues a different point but is complementary to that in the previous section: equation (1) cannot be used to test the Feldstein-Horioka hypothesis because saving and investment in the national accounts are related in such a way that regression (1) is a pointless exercise. We will argue that this regression is not a model in the sense that this term is used in econometrics, that is, an equation that contains an error term that is a random variable. The consequence is that simple reasoning leads to the result that $\beta^*$ must take on a value between 0 and 1 in most cases (whether it is close to 0 or to 1 is irrelevant), just as most of the literature has found. The surprise would have been to find otherwise, as we demonstrate below.

The OLS estimator of $\beta^*$ in equation (1) ($\beta^*_{OLS}$) is:

$$\beta^*_{OLS} = \frac{Cov(I_t, S_t)}{Var\ (S_t)} \tag{3}$$

As noted above, the national accounts give the identity of equation (2). Suppose a researcher estimated the regression:

$$I_t = \alpha + \beta S_t + \gamma KA_t + \varepsilon_t \tag{4}$$

where $\varepsilon$ is the error term. It should be self-evident that the error term ($\varepsilon$) in equation (4) is zero for every observation and that (estimated) $\alpha = 0$, $\beta = \gamma = 1$, and $R^2 = 1$. Consequently, adding to the earlier discussion about the inappropriateness of the series used to test the Feldstein-Horioka hypothesis, the accounting identity (2) poses a problem for the estimation and interpretation of $\beta^*$ in equation (1) as routinely done in the FHP literature. This is because the three series involved in the discussion of the Feldstein-Horioka hypothesis and puzzle are related through the accounting identity (2). This implies that the error term $u_t$ in equation (1) is the capital account ($KA_t$), not an unknown random term. To be precise, the error in equation (1) for each observation ($\hat{u}$) is (from equation (4) with $\alpha = 0,\ \beta = \gamma = 1$ and equation (1)):

$$\hat{u}_t = I_t - \hat{I}_t = KA_t - \left[\hat{\alpha}^* + (\hat{\beta}^* - 1)S_t\right] \qquad (5)$$

Equation (5) implies that:

(i) if $KA_t = 0, I_t = S_t$, then the estimation of equation (1) will yield $\hat{\alpha}^* = 0$ and $\hat{\beta}^* = 1$ and actual residuals $\hat{u}_t = 0$ (perfect fit);

(ii) if $KA_t = KA$ (constant), the identity is $I_t = S_t + KA$, then the estimation of equation (1) will yield $\hat{\alpha}^* = KA$, $\hat{\beta}^* = 1$, and $\hat{u}_t = 0$ (perfect fit);

(iii) if $S_t = 0$, therefore the identity is $I_t = KA_t$, then $\hat{\alpha}^* = \overline{KA}$ (where $\overline{KA}$ is the average value of $KA_t$) and $\hat{\beta}^* = 0$. Now, $\hat{u}_t = I_t - \hat{\alpha}^* = I_t - \overline{KA}$ (the fit of the regressions will be zero); and

(iv) if $S_t = S$ (constant), the identity is $I_t = S + KA_t$, then $\hat{\alpha}^* = S + \overline{KA}$, and $\hat{\beta}^* = 0$. In this case, $\hat{u}_t = I_t - \hat{\alpha}^* = I_t - (S + \overline{KA})$ (the fit of the regression will be zero).

We stress that these results follow because the three series are related through the accounting identity. Moreover, they do not require estimating regression (1).

The discussion above also implies that regression (1) can be interpreted as equation (4) but with the former incurring omitted-variable bias for excluding $KA_t$, which in general is neither constant nor zero (and neither is $S_t$). The interpretation of the OLS estimate of $\hat{\beta}^*$ in (1) is, therefore, that it is a biased estimate of the 'true' slope parameter $\beta$ in equation (4).

This can be seen as follows. Algebraically, the expected value of $\beta^*_{OLS}$ is:

$$E(\beta^*_{OLS}) = \beta + \gamma \frac{Cov(KA_t, S_t)}{Var(S_t)} \qquad (6)$$

where the "bias" due to the omission of $KA_t$ in equation (1) is $\gamma \frac{Cov(KA_t, S_t)}{Var(S_t)}$. However, because we know exactly what the omitted variable is, this is not the standard econometric problem, where there is an omitted but unknown variable (hence there is a true bias and, consequently, it makes sense to devise an econometric strategy to deal with it). For this reason, we refer to it as a pseudo bias, that is, $Pseudo\ Bias = \gamma \frac{Cov(KA_t, S_t)}{Var(S_t)}$. Moreover, because $\beta = \gamma = 1$ in equation (6) (from equation (4)), then $Pseudo\ Bias = \frac{Cov(KA_t, S_t)}{Var(S_t)}$, and we then have:

$$E(\beta^*_{OLS}) = 1 + \frac{Cov(KA_t, S_t)}{Var(S_t)} = 1 + Pseudo\ Bias \qquad (7)$$

Naturally, $Pseudo\ Bias = \frac{Cov(KA_t, S_t)}{Var(S_t)}$ is the coefficient $b$ in the auxiliary regression $KA_t = c + bS_t$. All this should have been known to the researcher if they had understood the nature of regression (1) given by the accounting identity in equation (2).

It is self-evident that, given equation (7), the following can be said about the expected value of $\beta^*_{OLS}$ :

$E(\beta^*_{OLS}) = 1$ (*Pseudo Bias* = 0) iff $Cov(KA_t, S_t) = 0$, or $|Cov(KA_t, S_t)| \ll Var(S_t)$ (8a)

$E(\beta^*_{OLS}) = 0$ (*Pseudo Bias* = -1) iff $Cov(KA_t, S_t) < 0$ and $|Cov(KA_t, S_t)| = Var(S_t)$ (8b)

$E(\beta^*_{OLS}) > 1$ (*Pseudo Bias* > 0) iff $Cov(KA_t, S_t) > 0$ (8c)

$E(\beta^*_{OLS}) < 0$ (*Pseudo Bias* < -1) iff $Cov(KA_t, S_t) < 0$ and $|Cov(KA_t, S_t)| > Var(S_t)$ (8d)

$0 < E(\beta^*_{OLS}) < 1$ (*Pseudo Bias* < 0) iff $Cov(KA_t, S_t) < 0$ and $|Cov(KA_t, S_t)| < Var(S_t)$ (8e)

Cases (8a)-(8b) correspond to the logical extremes of the Feldstein-Horioka thesis that $\beta^*$ should be close to zero (though not necessarily zero) and certainly below one. Our argument is that once the identity in equation (2) (or equation (4) in regression form) is recognized, it is self-evident that the coefficient $\beta^*$ in equation (1) must be less than 1 in most cases. The reason is that, in most countries, $b = \frac{Cov(KA_t, S_t)}{Var(S_t)} < 0$, a result that follows from the fact that $Cov(KA_t, S_t) < 0$. Researchers who have worked with the three variables $I_t$, $S_t$, and $KA_t$, know that the latter two variables are negatively correlated. This explains why the most likely outcome will be (8e).

Certainly, it is possible to find individual country cases that fit case (8b), that is, $\hat{\beta}^* = 0$, but requires $|Cov(KA_t, S_t)| = Var(S_t)$. Likewise, there could be countries that fit case (8c), that is, $\hat{\beta}^* > 1$, which requires $Cov(KA_t, S_t) > 0$, though we expect to find only a few such cases. Case (8d), $\beta^* < 0$ is a result difficult to explain in the context of the Feldstein-Horioka hypothesis. For this to happen, $|Cov(KA_t, S_t)| > Var(S_t)$. Our argument remains that, whatever result that regression (1) yields, it is the outcome of estimating a "quasi accounting identity" that does not test what the authors intended.

Some may argue at this point that all the above is known and implicit in the FHP literature. Although it is true that discussions in the FHP literature, and by Feldstein-Horioka originally, have referred to the three series in the identity, nobody has stated openly the obvious—that the series in regression (1) are related through an accounting identity with one missing variable—known to the researcher. We find it somewhat puzzling that Feldstein and Horioka themselves acknowledged the identity of equation (2) multiple times. First, they noted that "the excess of gross domestic investment over gross domestic saving is equal to the net inflow of foreign investment [i.e., the capital account]" (Feldstein & Horioka, 1980, p. 320). Also, "the identity of *national* saving and investment does not imply equality of *domestic* saving and investment. Because of international capital flows, domestic saving and investment can differ for very long periods of time" (Feldstein & Horioka, 1980, p. 320; emphasis in the original).[6] Despite these statements, they did not seem to realize what this meant for their regression and for their interpretation of it.

Continuing with Feldstein and Horioka's exposition, they remarked that "a regression of net foreign investment inflow to GDP on the domestic savings [sic] ratio would have a coefficient of $\beta^* - 1$" (Feldstein & Horioka, 1980, p. 320; using our notation for the estimated coefficient $\beta^*$).

[6] The accounting identity is also explicit in Obstfeld and Rogoff's (2001, p. 350) statement: "[FH regression] summarizes in a compact way the fact that OECD current accounts tend to be surprisingly small relative to total saving and investment, especially when one averages over any sustained period."

However, their $(\beta^* - 1)$ is, naturally, $b = \frac{Cov(KA_t, S_t)}{Var(S_t)}$ in the auxiliary regression above, what we labeled the pseudo bias in equation (7) is derived from the identity. Therefore, their summation that "Testing the hypothesis that $\beta$ equals one is therefore equivalent to testing the hypothesis that the international capital flows do not depend on domestic savings [sic] rates" (Feldstein & Horioka, 1980, p. 320) is tautological precisely because the capital account is the omitted variable (but known to the researcher) in their regression.

Feldstein and Horioka also wondered whether "the high coefficient in the relation between domestic investment and domestic saving may reflect the impact of some third variable" (Feldstein & Horioka, 1980, p. 322). From equation (2), this is obviously true. However, Feldstein and Horioka hypothesized that this variable could be, for instance, population growth or openness (exports plus imports over GDP). Neither variable worked (both were statistically insignificant). In this vein, Taylor (1994) argued that the standard Feldstein-Horioka high correlation between investment and saving is simply an artifact of omitted-variable bias. The high correlation between the two variables disappeared once the regression controlled for growth and demographics. However, we know that the missing variable is $KA_t$. This means that if an additional variable $X_t$ "works" when added to equation (1), it is because it is correlated with $KA_t$. This means that the higher the correlation between $KA_t$ and $X_t$, the closer the coefficients of both the saving rate and of $\mathrm{X_t}$ will be to 1 (and the closer the regression fit to 1). This contrasts with Feldstein and Horioka's various regressions adding a third variable, the intent of which was clearly to find a missing variable that reduced the coefficient of $X_t$. Population growth and openness are not correlated with $KA_t$ in a large cross-section of countries. This again is suggestive of not recognizing that the identity in equation (2) lies at the core of all their regressions.[7] We will return to this point in Section 4.

Finally, some authors have argued that the OLS estimates of equation (1) are probably biased as a result of the endogeneity of the saving rate and proposed to use instrumental variable (IV) estimation methods. Yet, it is not clear that this route has solved the conundrum as IV estimates are still relatively high (e.g., Feldstein and Horioka).

As noted above, a significant portion of the literature has focused on estimation issues such as the existence of a dynamic relationship between savings and investment, the possible cointegration between the series, and the estimation of error correction models. None of these matters and none of them will solve the conundrum at hand. It should be obvious by now that the estimation of equation (1) as an error correction model (ECM) (e.g., Sinha & Sinha, 2004; Westerlund, 2006; Nell & Santos, 2008) does not solve the problem discussed. Although it is true that an ECM can deal with the problem of unit roots in the investment and saving series (as shares of GDP), assuming these are present and the estimate of $\beta^*$ would be different from that in equation (1), this is not the problem at hand (and recall the discussion in the previous section about the nature of the series used).[8]

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[7] Given the accounting identity, the exercise could equally be run with the capital account as right-hand side variable, that is, $I_t = \alpha' + \beta' KA_t + \varepsilon_t$. The coefficients in regression (1) and in this one are related as follows: $\beta^* = 1 + \frac{(\beta'-1)Var(KA_t)}{Var\ (S_t)}$. If $\beta^* = 0$, then $\beta' = 1 - \frac{Var\ (S_t)}{Var(KA_t)}$.

[8] To see this, note first that equation (identity) (4) in ECM can be estimated, assuming an autoregressive distributive lag, as $\Delta I_t = \alpha_1 \Delta I_{t-1} + \alpha_2 \Delta S_t + \alpha_3 \Delta S_{t-1} + \alpha_4 \Delta KA_t + \alpha_5 \Delta K_{t-1} + \lambda_1 I_{t-1} + \lambda_2 S_{t-1} +$

Summing up, none of these arguments requires regression analysis, just simple reasoning. There is no econometric issue to solve (e.g., endogeneity of the saving rate) or the existence of an adjustment process to equilibrium that requires specific econometric techniques.

### Empirics: What Does the Feldstein-Horioka Regression Tell Us?

We are now in a position to consider what regressions of equation (1) actually do if they are not a test of the Feldstein-Horioka hypothesis. To document our arguments, we obtained consistent data to construct the identity $I_t \equiv S_t + KA_t$ for a sample of 70 countries for 1960–2019, and estimated regression (1).[9] Although it is true that, mathematically, the interpretation of regression (1) is that $(\partial I_t / \partial S_t) = \hat{\beta}^*$ (i.e., a \$1 increase in $S_t$ would result in a $\beta^*$increase in $I_t$), we stress that we do not interpret $\beta^*$ in terms of a retention coefficient, and its size (close to 0 or to 1) is irrelevant to the discussion at hand because, conceptually, it does not provide the answer to the question being asked, that is, how much saving is "retained" and translated into domestic investment. The discussion below, therefore, is based on our interpretation that $\beta^*$ is, by definition, $1 + \frac{Cov(KA_t, S_t)}{Var(S_t)}$, a result that was derived from the fact that the accounting identity equation (2) (equation (4) in regression form) was assumed to be the "true" model where $\beta = 1$.

Feldstein and Horioka argued that $\beta^*$ should be close to zero (though not necessarily zero) and certainly below one. The discussion about the possible values of $\beta^*$ in Section 3 was not based on statistical estimation. When this is done, then the coefficient will have a confidence interval. We estimated equation (1) and divided countries into four groups according to the size and statistical significance of the estimated $\beta^*$: (a) those with $\hat{\beta}^* = 0$; (b) those with $0 < \hat{\beta}^* < 1$ (split between countries where $0 < \hat{\beta}^* < 0.5$ and countries where $0.5 < \hat{\beta}^* < 1$); (c) those with $\hat{\beta}^* \geq 1$; and (d) those with $\hat{\beta}^* < 0$. Cases (a)-(b) would be interpreted in the literature as evidence that there is capital mobility (the higher, the smaller $\hat{\beta}^*$), that is, that world capital markets are relatively integrated. Case (c) would be interpreted as evidence of low or no capital mobility.

Estimation results are shown in Tables 2 ad 3. They provide the estimates of $\beta^*$, the numerator and denominator of the pseudo bias, and the 95% confidence interval. Table 1, Panel A, shows the pooled regressions. Panel B shows the individual-country regressions where $\hat{\beta}^* = 0$. Panel C shows the countries where $0 < \hat{\beta}^* < 1$ (the latter arbitrarily split between those countries where $0 < \hat{\beta}^* < 0.5$ (panel C.1), and those countries where $0.5 < \hat{\beta}^* < 1$ (panel C.2)). Table 2 provides the country results for the cases where $\hat{\beta}^* \geq 1$ (panel A) and $\hat{\beta}^* < 0$ (panel B). As indicated in the discussion

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$\lambda_3 KA_{t-1}$ (again, no error term). It is obvious that the coefficients $\alpha_2$ ($\Delta S_t$) and $\alpha_4$ ($\Delta KA_t$) will be 1, those of all other variables will be 0, and the regression will yield a perfect fit. This can be corroborated. The ECM corresponding to equation (1) is: $\Delta I_t = \alpha^* + \gamma_1 \Delta I_{t-1} + \gamma_2 \Delta S_t + \gamma_3 \Delta S_{t-1} + \delta_1 I_{t-1} + \delta_2 S_{t-1} + \varepsilon_t$. The "long-run elasticity" of investment with respect to the saving rate in this representation is calculated as: $\theta^* = -(\frac{\delta_2}{\delta_1})$. Yet, we return to the same discussion as above about the pseudo bias in the coefficient of the saving rate.

[9] The data source is the Penn World Table (version 10.0). Other papers testing the FHP (e.g., Sinha & Sinha, 2004; Adedeji & Thornton, 2008) have also used data from the Penn World Tables.

above, $Cov(KA_t, S_t) < 0$ in column (2) in all cases except for Nepal and Slovenia. For these two, the $Pseudo\ Bias$ is positive (Case (8c) above).

We highlight the following results for $\beta^*$: (a) the coefficients of the five pooled regressions are positive and oscillate between 0.36-0.39 for the first three larger samples (all, OECD, developing), and 0.64-0.68 for the Feldstein-Horioka sample (pooled data, and averaging per country as in Feldstein-Horioka), all statistically different from zero and smaller than 1; (b) there are 18 country cases where $\hat{\beta}^* = 0$ and another 18 where $0 < \hat{\beta}^* < 0.5$ (i.e., relatively small values). Probably the literature would interpret all these 36 as corroboration of the Feldstein-Horioka hypothesis; (c) there are 14 cases where $0.5 < \hat{\beta}^* < 1$ (i.e., relatively high values but all smaller than 1) and 14 cases where $\hat{\beta}^* \geq 1$ (the null hypothesis that $\hat{\beta}^*$ is statistically greater than 1 cannot be rejected in two cases). The literature would probably interpret these 28 cases as a rejection of the Feldstein-Horioka hypothesis; and (d) there are six cases with $\hat{\beta}^* < 0$, which result from a very large negative $Pseudo\ Bias$. [10]

**Table 2**

*Feldstein-Horioka Regressions I*

| **Country** | $Cov(KA_t, S_t)$ (2) | $Var(S_t)$ (3) | $b = Pseudo\ Bias = \frac{Cov(KA_t, S_t)}{Var\ (S_t)}$ (4) | $\hat{\beta}^* = 1 + Pseudo\ Bias$ (5) | **95% Confidence Interval for $\hat{\beta}^*$** (6) |
|---|---|---|---|---|---|
| **A. Pooled Regressions** | | | | | |
| All countries (1960-2019) | -.015174 | .024824 | -0.6113 | 0.3887*** | 0.3718, 0.4057 |
| OECD (1960-2019) | -.005527 | .008619 | -0.6412 | 0.3588*** | 0.3306, 0.3869 |
| Developing economies (1960-2019) | -.019253 | .031924 | -0.6031 | 0.3969*** | 0.3743, 0.4195 |
| FH countries (1960-1974) pooled data | -0.0020 | 0.0057 | -0.3584 | 0.6416*** | 0.5720, 0.7113 |
| FH countries (1960-1974) averaged | -0.0017 | 0.0052 | -0.3199 | 0.6801*** | 0.4383, 0.9218 |
| **B. Countries with $\hat{\beta}^* = 0$: high degree of capital mobility in the FH terminology** | | | | | |
| Belgium | -0.0010 | 0.0012 | -0.8358 | 0.1643 | -0.0636, 0.3923 |
| Colombia | -0.0009 | 0.0009 | -0.9994 | 0.0006 | -0.2887, 0.2900 |
| Denmark | -0.0029 | 0.0029 | -1.0180 | -0.0180 | -0.1315, 0.0954 |
| China, Hong Kong SAR | -0.0069 | 0.0074 | -0.9428 | 0.0572 | -.00932, 0.2075 |
| Iran | -0.0095 | 0.0108 | -0.8788 | 0.1212 | -0.0072, 0.2497 |
| Luxembourg | -0.0163 | 0.0176 | -0.9229 | 0.0771 | -0.0301, 0.1842 |
| Netherlands | -0.0009 | 0.0009 | -1.0404 | -0.0404 | -0.3720, 0.2912 |
| New Zealand | -0.0003 | 0.0004 | -0.7830 | 0.2170 | -0.1419, 0.5758 |
| Singapore | -0.0585 | 0.0590 | -0.9904 | 0.0096 | -0.1174 ,0.1367 |
| Switzerland | -0.0019 | 0.0014 | -1.2969 | -0.2969 | -0.6349, 0.0411 |
| Aruba | -0.0189 | 0.0217 | -0.8947 | 0.1053 | -0.0226, 0.2332 |
| Bahrain | -0.0160 | 0.0129 | -1.2435 | -0.2435 | -0.5557, 0.0687 |
| Bulgaria | -0.0017 | 0.0020 | -0.8307 | 0.1693 | -0.2443, 0.5829 |
| Philippines | -0.0009 | 0.0009 | -0.9605 | 0.0395 | -0.2220, 0.2584 |

[10] Differences in the magnitude of $\beta^*$ for the 70 countries are the result of differences in both $Cov(KA_t, S_t)$ in the numerator of the $Pseudo\ Bias$ and $Var(S_t)$ in the denominator, as the variances of both are not statistically different (the ratio of the two variances under the null that they are equal, follows an F-distribution).

| | | | | | |
|---|---|---|---|---|---|
| Saudi Arabia | -0.0193 | 0.0218 | -0.8858 | 0.1142 | -0.0194, 0.2478 |
| Azerbaijan | -0.0342 | 0.0311 | -1.1008 | -0.1008 | -0.3058, 0.1043 |
| Belarus | -0.0015 | 0.0019 | -0.8256 | 0.1744 | -0.1134, 0.4622 |
| Slovakia | -0.0003 | 0.0004 | -0.7870 | 0.2130 | -0.4631, 0.8891 |
| **C. Countries where $0 < \widehat{\beta}^{*} < 1$: some degree of capital mobility in the FH terminology** | | | | | |
| **C.1 Cases where $0 < \widehat{\beta}^{*} < 0.5$** | | | | | |
| Algeria | -0.0041 | 0.0073 | -0.5646 | 0.4354*** | 0.2374, 0.6334 |
| Argentina | -0.0007 | 0.0009 | -0.7703 | 0.2297* | 0.2297, 0.1106 |
| Canada | -0.0004 | 0.0005 | -0.7469 | 0.2531* | 0.0579, 0.4483 |
| Costa Rica | -0.0028 | 0.0049 | -0.5783 | 0.4217*** | 0.3283, 0.5152 |
| Egypt | -0.0036 | 0.0057 | -0.6210 | 0.3790*** | 0.3080, 0.4500 |
| Indonesia | -0.0018 | 0.0031 | -0.5979 | 0.4021* | 0.0045, 0.7998 |
| Ireland | -0.0308 | 0.0386 | -0.7989 | 0.2011*** | 0.1217, 0.2805 |
| Kenya | -0.0008 | 0.0011 | -0.7003 | 0.2997* | 0.0134, 0.5859 |
| Mexico | -0.0003 | 0.0004 | -0.6847 | 0.3153* | 0.0354, 0.5953 |
| Pakistan | -0.0007 | 0.0009 | -0.7139 | 0.2861*** | 0.1788, 0.3933 |
| Panama | -0.0075 | 0.0111 | -0.6749 | 0.3251*** | 0.1549, 0.4952 |
| United Kingdom | -0.0008 | 0.0011 | -0.7698 | 0.2302* | 0.0546, 0.4059 |
| United States | -0.0004 | 0.0007 | -0.5762 | 0.4238*** | 0.2798, 0.5677 |
| Venezuela | -0.0264 | 0.0358 | -0.7361 | 0.2639*** | 0.1341, 0.3936 |
| Angola | -0.0083 | 0.0141 | -0.5917 | 0.4083** | 0.1163, 0.7003 |
| Albania | -0.0065 | 0.0112 | -0.5796 | 0.4205*** | 0.2514, 0.5896 |
| United Arab Emirates | -0.0107 | 0.0187 | -0.5700 | 0.4300*** | 0.2776, 0.5823 |
| Cayman Islands | -0.0016 | 0.0022 | -0.7462 | 0.2538** | 0.0844, 0.4233 |
| **C.2 Cases where $0.5 < \widehat{\beta}^{*} < 1$** | | | | | |
| Austria | -0.0004 | 0.0018 | -0.2230 | 0.7770*** | 0.6149, 0.9392 |
| Bangladesh | -0.0019 | 0.0101 | -0.1902 | 0.8098*** | 0.7534, 0.8661 |
| Chile | -0.0050 | 0.0103 | -0.4796 | 0.5204*** | 0.4331, 0.6077 |
| Cyprus | -0.0061 | 0.0221 | -0.2758 | 0.7242*** | 0.6062, 0.8422 |
| Finland | -0.0013 | 0.0030 | -0.4372 | 0.5628*** | 0.3127, 0.8129 |
| Germany | -0.0006 | 0.0017 | -0.3704 | 0.6296*** | 0.2742, 0.9850 |
| Greece | -0.0016 | 0.0084 | -0.1863 | 0.8137*** | 0.7151, 0.9122 |
| India | -0.0020 | 0.0074 | -0.2721 | 0.7279*** | 0.6788, 0.7770 |
| Malaysia | -0.0017 | 0.0060 | -0.2853 | 0.7147*** | 0.5240, 0.9055 |
| Peru | -0.0017 | 0.0047 | -0.3528 | 0.6472*** | 0.5658, 0.7286 |
| Republic of Korea | -0.0036 | 0.0123 | -0.2933 | 0.7067*** | 0.6304, 0.7830 |
| South Africa | -0.0013 | 0.0028 | -0.4592 | 0.5408*** | 0.3858, 0.6958 |
| Taiwan | -0.0019 | 0.0050 | -0.3711 | 0.6289*** | 0.5063, 0.7515 |
| Turkey | -0.0009 | 0.0028 | -0.3081 | 0.6919*** | 0.5110, 0.8728 |

Source: Authors.

Note: * denotes statistical significance at the 95 percent level, ** 99 percent level, and *** 99.9 percent level.

## Table 3

*Feldstein-Horioka Regressions II*

| **Country** | $Cov(KA_t, S_t)$ (2) | $Var(S_t)$ (3) | $b = Pseudo\ Bias = \frac{Cov(KA_t, S_t)}{Var\ (S_t)}$ (4) | $\widehat{\beta}^{*} = 1 + Pseudo\ Bias$ (5) | **95% Confidence Interval for $\widehat{\beta}^{*}$** (6) |
|---|---|---|---|---|---|
| **A. Countries where $\widehat{\beta}^{*} \geq 1$: low degree of capital mobility in the FH terminology** | | | | | |
| Australia | -0.0001 | 0.0004 | -0.1534 | 0.8466*** | 0.5300, 1.1632 |
| Bhutan | -0.0007 | 0.0024 | -0.2866 | 0.7134*** | 0.3687, 1.0580 |
| Brazil | -0.0001 | 0.0007 | -0.1985 | 0.8015*** | 0.5718, 1.0311 |

| | | | | | |
|---|---|---|---|---|---|
| China | -0.0005 | 0.0112 | -0.0455 | 0.9545*** | 0.9041, 1.0049 |
| France | -0.0001 | 0.0007 | -0.1272 | 0.8728*** | 0.6963, 1.0493 |
| Italy | -0.0002 | 0.0005 | -0.5153 | 0.4847*** | 0.2696, 0.6998 |
| Japan | -0.0004 | 0.0029 | -0.1262 | 0.8738*** | 0.7415, 1.0060 |
| Morocco | -0.0010 | 0.0101 | -0.0989 | 0.9011*** | 0.7758, 1.0265 |
| Nepal | 0.0002 | 0.0066 | 0.0341 | 1.0341*** | 0.8759, 1.1923 |
| Nigeria | -0.0059 | 0.0596 | -0.0986 | 0.9014*** | 0.7955, 1.0073 |
| Slovenia | 0.0002 | 0.0005 | 0.3966 | 1.3966*** | 0.6958, 2.0975 |
| Spain | -0.0001 | 0.0005 | -0.1422 | 0.8578*** | 0.5121, 1.2035 |
| Thailand | -0.0006 | 0.0044 | -0.1396 | 0.8604*** | 0.7141, 1.0067 |
| Russian Federation | -0.0005 | 0.0048 | -0.0934 | 0.9066*** | 0.7531, 1.0600 |
| **B. Countries where $\hat{\beta}^* < 0$** | | | | | |
| Norway | -0.0226 | 0.0150 | -1.5067 | -0.5067*** | -0.5943, -.4191 |
| Sweden | -0.0018 | 0.0012 | -1.4793 | -0.4793*** | -0.7051, -0.2535 |
| Antigua and Barbuda | -0.0568 | 0.0501 | -1.1342 | -0.1342* | -0.2578. -0.0106 |
| Bahamas | -0.0117 | 0.0069 | -1.6839 | -0.6839*** | -1.0103, -0.3575 |
| Belize | -0.0090 | 0.0078 | -1.1559 | -0.1559** | -0.2652, -0.0466 |
| Brunei Darussalam | -0.0126 | 0.00743 | -1.6884 | -0.6884*** | -1.0110, -0.3658 |

Source: Authors.
Note: * denotes statistical significance at the 95 percent level, ** 99 percent level, and *** 99.9 percent level.

### The Additional Missing Variable: "Where is Waldo?"[11]

We can now illustrate our points in Section 3 regarding Feldstein and Horioka's search for a missing variable using some examples (from Table 2). Consider equation (9), where $\beta_S^*$ is the coefficient on saving, $X_t$ is a "third" variable or a vector of several of them, with $\theta_X^*$ being the coefficient(s), and $\xi$ is an error term:

$$I_t = \alpha^* + \beta_S^* S_t + \theta_X^* X_t + \xi_t \qquad (9)$$

We argued above, commenting on the Feldstein-Horioka results, that if any added variable to regression (1) (e.g., population growth, openness) works econometrically, it is because it must be correlated with $KA_t$ (the missing variable) in the cross-section of countries. Moreover, when this happens, the coefficient on the saving rate must approximate one, not zero. Population growth and openness did not do the job in their case, the same as with our data set, that is, both variables are statistically insignificant because they cannot track the share of the capital account in GDP in the cross-section of countries. To see why this is the case, Table 4 presents individual-country results for the United States, Canada, Denmark, and the Philippines.

The first row for each country shows the results from Table 2 for Canada and the United States (both with $0 < \hat{\beta}^* < 0.5$), and for Denmark and the Philippines (both with $\hat{\beta}^* = 0$). Coefficients ($\theta_X^*$) for the variables tested in separate regressions as $X_t$ are in columns 3 through 8. Like Feldstein and Horioka, we also tested the role of population growth and openness (ratio of exports plus imports over GDP, $Openness$). Population growth is statistically insignificant in all four cases.

[11] *Where is Waldo?* is a children's game where Waldo, a little guy wearing a red-and-white-striped shirt, bobble hat, and glasses, is hidden. The purpose of the game was to find the character. It was created by British children's book illustrator Martin Hanford in 1987 under the original title *Where is Wally?*

We then tested the level of population ($Pop$). The third variable we tested, $\frac{b_0+b_1t}{1+b_2t+b_3t^2}$, a function of time ($t$), is derived by fitting a nonlinear regression function by least squares. For the United States, columns 3, 4, and 5 show equation (9) estimated with three variants of $X_t$, $Pop$, $Openness$, or $\frac{b_0+b_1t}{1+b_2t+b_3t^2}$. In all three cases, the regression fit is significantly higher than that obtained in the regression with $S_t$ alone in the top row (seen in a higher adjusted $R^2$ in column 9 relative to that in the top row). Note that the improved fit here results in much higher values of $\beta_S^*$ (approximating 1, rather than $\beta_S^*$ closer to zero) and the constant term ($\alpha^*$) becomes statistically insignificant, consistent with the (regression of the) identity).

**Table 4**

*Estimation Results of Equation (9)*

| | | | $\theta_X^*$, where $X_t$ is: | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Country** | $\hat{\alpha}^*$ (1) | $\hat{\beta}_S^*$ (2) | $Pop$ (3) | $Openess$ (4) | $\frac{b_0+b_1t}{1+b_2t+b_3t^2}$ (5) | $\frac{cos(t^{0.6})}{25}$ (6) | $\frac{sin\left(\frac{t-1}{9}\right)}{10}$ (7) | $\frac{sin((0.9t)^{0.75})}{13}$ (8) | **Adj. $R^2$** (9) |
| United States 1960-2019 | 0.15*** | 0.42*** | | | | | | | 0.36 |
| | -0.05 | 0.92*** | 0.35*** | | | | | | 0.52 |
| | 0.01 | 0.88*** | | 0.21*** | | | | | 0.57 |
| | 0.01 | 0.97*** | | | 0.93*** | | | | 0.67 |
| | | | | | | | | | |
| Canada 1960-2019 | 0.18*** | 0.25** | | | | | | | 0.10 |
| | 0.18*** | 0.23** | 0.05 | | | | | | 0.10 |
| | 0.19*** | 0.19* | | 0.02 | | | | | 0.10 |
| | 0.19*** | 0.22** | | | | | | | 0.10 |
| | 0.16*** | 0.35*** | | | | 0.34*** | | | 0.32 |
| | | | | | | | | | |
| Denmark 1960-2019 | 0.27*** | -0.02 | | | | | | | -0.02 |
| | 0.24*** | -0.05 | 0.69 | | | | | | -0.03 |
| | 0.26*** | 0.13 | | -0.04* | | | | | 0.03 |
| | 0.26*** | 0.03 | | | | | | | -0.03 |
| | 0.15*** | 0.41*** | | | | | 0.41*** | | 0.46 |
| | | | | | | | | | |
| Philippines 1970-2019 | 0.18*** | 0.04 | | | | | | | -0.02 |
| | 0.18*** | 0.04 | -0.001 | | | | | | -0.04 |
| | 0.13*** | 0.20 | | 0.09 | | | | | 0.01 |
| | 0.19*** | -0.01 | | | | | | | -0.04 |
| | 0.02*** | 0.23*** | | | | | | 0.39*** | 0.49 |

Source: Authors

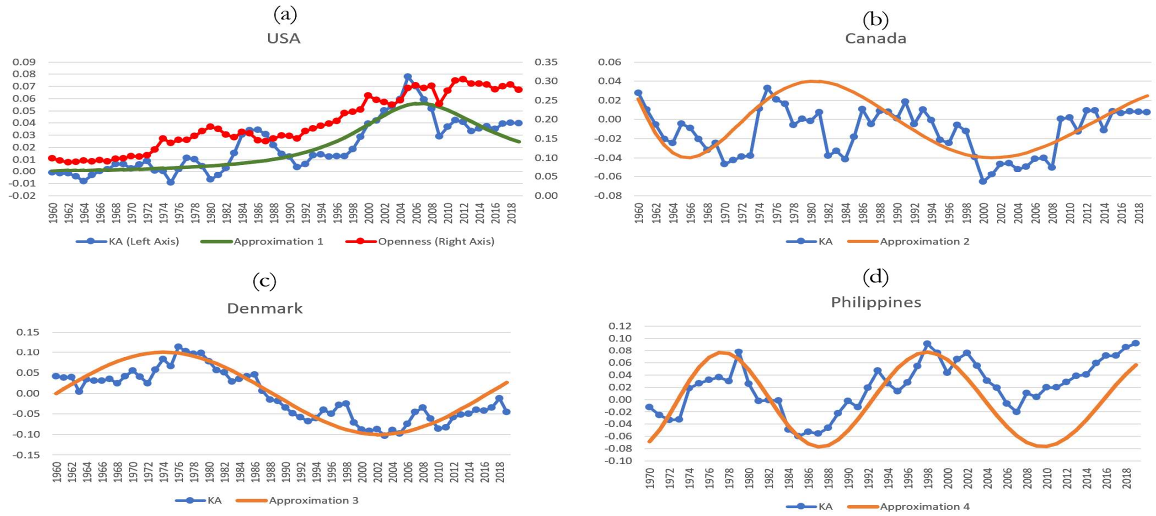
Note: * denotes statistical significance at the 95 percent level, ** 99 percent level, and *** 99.9 percent level.

Figure 1, panel (a) explains why: $Pop$, $Openness$, and $\frac{b_0+b_1t}{1+b_2t+b_3t^2}$ in columns 3, 4 and 5, are highly correlated with $KA$ for the United States, all of which basically rise through time. By contrast, the coefficients for $Pop$, and $Openness$ for Canada, Denmark, and the Philippines in Table 4, are not statistically significant and do not improve the fit as measured by the adjusted $R^2$, versus the regressions in the top rows of the respective countries. Figures 1, panels (b), (c), and (d) show why—

each of these countries' $KAs$ behave much differently from that of the United States. Because all three countries' $KAs$ exhibit wave-like long-run patterns, we show how different trigonometric functions of time approximate them for each country (obviously, other approximations are possible). These trigonometric functions are the $X_t$ variables in columns 6, 7, and 8 of Table 4. As expected, each is statistically significant, raising the adjusted $R^2$ relative to those of the regressions in the first row for each country. More importantly, in each case, $\beta_S^*$ increases relative to its value in the country's first row. For both Denmark and the Philippines, it becomes statistically significant. Again, as above, every part of this is entirely expected when recognized that the identity in equation (2) is what lies beneath regressions on equation (1).

**Figure 1**

*Approximations to the Capital Account (KA) through Population, Openness (United States), and Trigonometric Functions (Canada, Denmark, and Philippines)*




Source: Authors

Note: $KA$ is the capital account over GDP; $Openness$ is the ratio of exports plus imports over GDP; $Pop$ is population in billions; $Approximation\ 1 = \frac{b_0+b_1t}{1+b_2t+b_3t^2}$ Approximation 2 $= \frac{cos(t^{0.6})}{25}$; Approximation 3 $= \frac{sin\left(\frac{t-1}{9}\right)}{10}$; Approximation 4 $= \frac{sin((0.9t)^{0.75})}{13}$.

Overall, the foregoing discussion of Table 4 and the examples in Figure 1 illustrate that the search for "missing variables" to explain the results in equation (1) in the FHP literature suggests a lack of recognition of the underlying identity equation (2). Likewise, any estimated value of the coefficient $\beta^*$ on $S_t$ in equation (1) that is not equal to 1 necessarily suggests this same lack of recognition.

## Conclusions

For over four decades, researchers have estimated the regression of the investment rate on the saving rate to test the hypothesis that financial capital flows move across borders. Because these regressions often have yielded coefficients (significantly) greater than zero, authors have rejected this hypothesis.

This led to the so-called Feldstein-Horioka puzzle. First, we have shown that, since 1980, researchers have used conceptually wrong series to test a most important hypothesis in macroeconomics. Unfortunately, the correct series are not collected currently. Seemingly counterintuitive results have kept the profession digging (through different techniques) further along this research program for four decades without seeing the light.

Second, we have shown that these regressions miss the crucial point that, by adding the capital account on the right-hand side, they become an accounting identity. Consequently, we have argued that the Feldstein-Horioka regression is a quasi-accounting identity. The implication is that the finding in this regression of a coefficient of the saving rate between zero and one (with the precise value being an irrelevant issue) is a foregone result with not much economic interest. This conclusion, together with the fact that the saving and investment series in the national accounts are not the ones that should be used to test the Feldstein-Horioka hypothesis, casts doubt on the soundness and strength of one of the greatest puzzles in macroeconomics.

We conclude that the profession should abandon this research program (as discussed in this paper), focus on collecting the correct series to properly test the Feldstein-Horioka hypothesis, and think carefully about the testing strategy.

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**APPENDIX: Decomposing the Capital Account**

As our measure $KA$ includes both the capital account and the statistical discrepancy, we can further illustrate the point about the pseudo bias. Denoting the "true" measure of the capital account by $KA^*$ and the statistical discrepancy by $SD$ (both as a percent of GDP), we have $KA \equiv KA^* + SD$, where $SD$ is the negative of the officially reported statistical discrepancy.[12] Consequently, the pseudo bias in column (5) of Tables 2 and 3 is really the sum of the pseudo biases for $KA^*$ and $SD$.

Table A1 presents the estimation results of equation (1) augmented with the additional regressor $KA^*$ as in equation (A1) below:

$$I_t = \alpha^* + \beta_S^* S_t + \delta_{KA^*}^* KA_t^* + \epsilon_t \quad \text{(A1)}$$

As above in equation (5), the error of each observation is given by the difference between equation (4) with $\alpha = 0$, $\beta = \gamma = 1$ and the estimated equation (A1). That is, $\hat{e}_t = I_t - \hat{I}_t = SD_t - [\hat{\alpha}^* + (\hat{\beta}_S^* - 1)S_t + (\hat{\delta}_{KA^*}^* - 1)KA_t^*]$.

Certainly, adding $KA_t^*$ as an additional regressor should improve the results. Indeed, the coefficient of the saving rate ($\beta_S^*$) in Table A1 starts moving in the direction determined by equation (4), that is, unity. In all cases except five, $0 < \hat{\beta}_S^* \leq 1$ and $\hat{\beta}_S^*$ is statistically different from zero (e.g., compare the coefficient of the saving rate for Norway in Table A1 to that in Table 3). In some cases, $\hat{\beta}_S^*$ is nearly 1 (e.g., Hong Kong, SAR, Denmark, and Belgium). The difference with respect to the complete identity in equation (2) is that equation (A1) omits the $SD$. This illustrates how the omission of $KA$ in equation (1) causes a very large pseudo bias in the coefficient of the saving rate in these countries.

**Table A1**

*Estimation results of Equation (A1)*

| Country | $\alpha^*$ (1) | $\beta_S^*$ (2) | $\delta_{KA^*}^*$ (3) |
|---|---|---|---|
| **Countries with $\beta^* < 0$ in Table 3** | | | |
| **1960-2019** | | | |
| Norway | 0.13*** | 0.52*** | 0.53*** |
| Sweden | 0.11** | 0.16*** | 0.11*** |
| **1970-2019** | | | |
| Antigua and Barbuda | 0.05 | 0.33*** | 0.38*** |
| Bahamas | 0.08** | 0.55*** | 0.80*** |
| Belize | 0.08*** | 0.20*** | 0.48*** |
| Brunei-Darussalam | 0.14* | 0.55*** | 0.73*** |
| **Countries with $\beta^* = 0$ *(i.e., statistically insignificant)* in Table 2** | | | |
| **1960-2019** | | | |

[12] We use the variable "csh_r," which is the "share of residual trade and GDP statistical discrepancy at current purchasing power parities" from Penn World Table (version 10.0), as in the previous note. According to Feenstra et al. (2015), this statistical discrepancy is the difference between total expenditure C + I + G + X - M and total GDP. Depending on the country data, csh_r may have residual trade, which includes trade in services.

| | | | |
|---|---|---|---|
| Belgium | 0.03** | 0.89*** | 0.97*** |
| **Colombia** | **0.21*** ** | **0.06** | **0.38** |
| Denmark | -0.02 | 0.97*** | 0.92*** |
| China, Hong Kong, SAR | 0.00 | 1.00*** | 1.00*** |
| Iran | 0.23*** | 0.17** | 0.04 |
| Luxembourg | 0.12*** | 0.22*** | 0.40*** |
| Netherlands | 0.03 | 0.78*** | 0.69*** |
| New Zealand | 0.15*** | 0.33** | 0.59*** |
| Singapore | 0.09*** | 0.56*** | 0.55*** |
| Switzerland | -0.08*** | 1.11*** | 1.36*** |
| **1970-2019** | | | |
| Aruba | -0.01* | 1.08*** | 0.98*** |
| Bahrain | 0.14** | 0.44*** | 0.48*** |
| **Bulgaria** | **0.11*** ** | **-0.20** ** | **0.97*** ** |
| **Philippines** | **0.14*** ** | **0.07** | **0.87*** ** |
| Saudi Arabia | 0.12*** | 0.85*** | 0.84*** |
| **1990-2019** | | | |
| **Azerbaijan** | **0.20*** ** | **-0.20*** ** | **-0.14** |
| **Belarus** | **0.15*** ** | **0.11** | **0.22*** ** |
| Slovakia | 0.08** | 0.62*** | 0.68*** |
| **Countries with $\beta^* > 1$ in Table 3** | | | |
| **1960-2019** | | | |
| Nepal | 0.06*** | 0.70*** | 0.74*** |
| **1990-2019** | | | |
| Slovenia | -0.08** | 1.20*** | 0.81*** |

Source: Authors.
Note: * denotes statistical significance at the 95 percent level, ** 99 percent level, and *** 99.9 percent level.

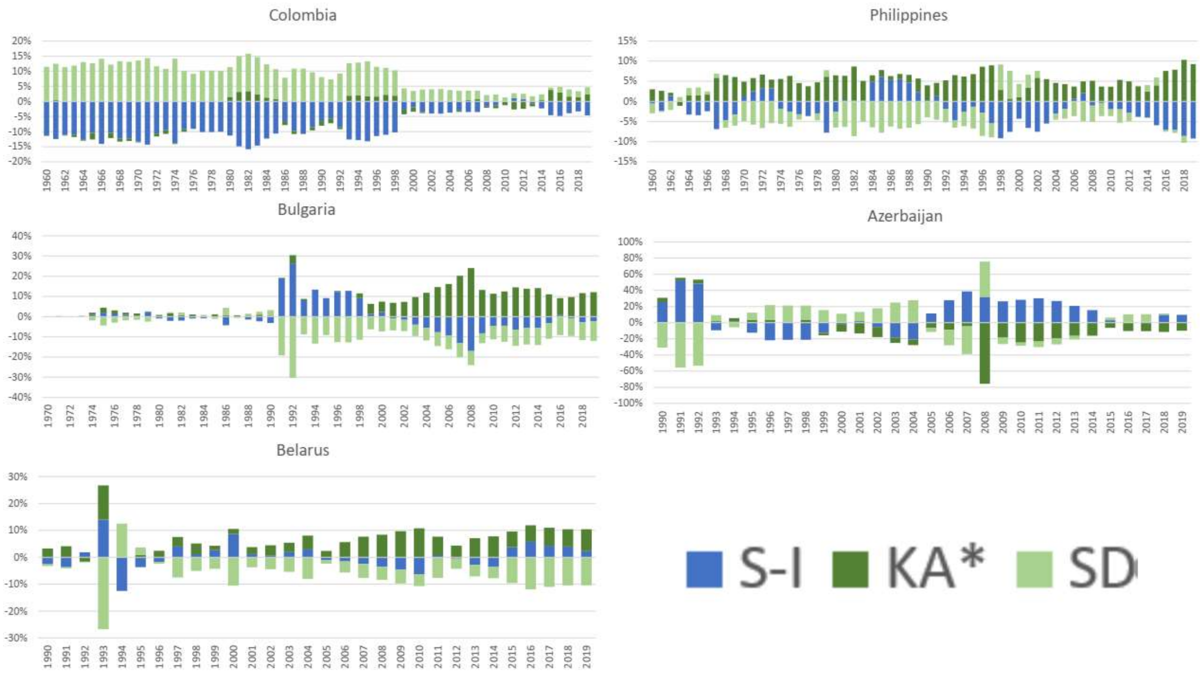
There are now only five cases where results are still rather poor (these are in bold in Table A1). All are cases for which $Bias_{SD}$ drives $Bias$: Colombia, Philippines, Bulgaria, Azerbaijan, and Belarus (the other two being Luxembourg and New Zealand; both now show $0 < \beta_S^* \leq 1$ in Table A1). Obviously, $SD$ causes the large pseudo bias. If regression (A1) is instead estimated for these countries with $SD$ and $KA^*$switching places, then, as expected, $0 < \beta_S^* \leq 1$. To better understand this, it is interesting to consider for these five cases the path of the relative sizes of $S$ and $I$. For this, we rearrange the saving-investment identity: because $I \equiv S + KA^* + SD$, we therefore have:

$$(S - I) + (KA^* + SD) \equiv 0 \qquad \text{(A2)}$$

Figure A1 shows $(S - I)$, $KA^*$And $SD$, for the five outlier countries in Table A1. For all five, it is clear that the very large $SD$ values cause the estimated coefficients in Table A1 to deviate substantially from 1. We conjecture that in these cases, this reflects significant measurement problems.

**Figure A1**

*Countries in Table A1 with Large $SD$*




Source: Authors