International Capital Mobility under the Variable Real Interest Rate: Reassessment of Feldstein-Horioka Puzzle

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Abstract

This paper examines empirically the international capital mobility for several countries. The novelty of this paper is to develop a theory-based estimation method under the assumption of a variable real interest rate. Since the real interest rates are variable over both countries and time in the real world, it is more appropriate to assume that capital is sensitive to the real interest rate difference. The empirical results show that Singapore is a free capital mobile economy while India is a capital immobile economy.

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1 Introduction

Whether or not capital is perfectly mobile across countries is one of the most controversial issues in Macroeconomics that remains unsolved so far. Base on their empirical analysis, Feldstein and Horioka (1980) claimed that even in major industrial countries, capital mobility may be limited. This is known as Feldstein-Horioka puzzle. Not only empirical studies but also theoretical contributions have since attempted to solve this puzzle. However, results of empirical studies vary over a wide range and thus the interpretation differ from author to author.

This variation in results basically comes from two reasons. One is the problem of the measurement of international capital mobility, and the other is its interpretation. There have arisen mainly two methods to measure the degree of international capital mobility. Most common method to test the hypothesis of capital mobility is to estimate the correlation between national saving and investment. This was initiated by Feldstein-Horioka(1980), and consisted of estimation of the following cross-section regression;

$$\frac{I_i}{Y_i} = \alpha + \beta \, \frac{S_i}{Y_i} + \epsilon_i$$

According to the hypothesis, a perfect open economy allows saving to go wherever the return is the highest, and hence, β should equal zero. On the other hand, in a completely closed economy β should equal unity. Feldstein and Horioka find that β is significantly different from zero but not significantly different from 1. They, therefore, conclude that capital mobility is not perfect and that most of national saving ends up augmenting the domestic capital stock, at least in their sample of OECD countries. The estimated value of β is interpreted as a measure of the effect of a sustained increase in a country's saving rate on its investment rate.

However, if there exists high correlation between investment and saving rates, it does not, in itself, provide evidence against capital mobility, and vice versa. A variety of shocks may induce a positive correlation between the two. A persistent productivity shock would raise savings because wages are temporarily high, but would also raise investment since capital is more productive.

The other method, based on the theory of intertemporal optimal consumption, developed by, for example, Roubini (1988), Ghosh (1995), Shibata and Shintani (1998), and others. All researchers who apply this method use time series data. However, it is rather surprising that they all (with no exception) estimate the hypothesis under the small open economy with perfect capital mobility assumption, even though they try to investigate the degree of capital mobility.

Small open economy with perfect capital mobility assumption implies that the domestic interest rate equals the (fixed) world interest rate. The small open economy takes the world real interest rate as given. As mentioned above, this assumption is a bit strange, because it is known that there is no country with perfect capital mobility in the real world. Further, it is not appropriate to assume that the domestic interest rate does not fluctuate or remains tied with the world interest rate in the long period (remember they all use time series data).

This paper investigates the degree of international capital mobility based on the optimal consumption with the varying real interest rate theory. The paper is organized as following. Section 2 shows the theory of intertemporal optimal consumption with varying real interest rate which will be used for empirical studies in the later sections. Section 3 describes the empirical models. Section 4 contains the empirical results. Section 5 concludes the paper.

2 Intertemporal Optimal Consumption and the Real Interest Rate

A representative agent maximizes her lifetime utility subject to her budget constraint,

$$\begin{aligned} max \quad & E\sum_{t=0}^{\infty}\beta^{\,t}\,u(c_t) \\ s.t. \quad & a_{t+1} = (1+r_t)\,a_t + y_t - c_t - i_t - g_t, \end{aligned}$$

where, y_t, c_t, i_t, g_t, a_t, and r_t are income, consumption, investment, government expenditure, asset, and real interest rate, respectively. All variables are in real terms. Discount rate β equals $\frac{1}{1+\rho}$, where ρ is a time preference. $u(c_t)$ is instantenious utility function, and I assume it is a constant relative risk aversion, that is,

$$u(c_t) = \frac{c^{1-\alpha}-1}{1-\alpha}.$$

From the first order condition and Benveniste and Schinekman conditions, the Euler equation is,

$$E\left[\frac{\beta\, c_{t+1}^{-\alpha}\,(1+r_{t+1})}{c_t^{-\alpha}}\right] = 1.$$

Then, the Euler equation can be expressed as

$$\frac{1+r_{t+1}}{1+\rho}\,\frac{c_{t+1}^{-\alpha}}{c_t^{-\alpha}} = 1 + e_{t+1}, \tag{1}$$

assuming $E(e_{t+1}) = 0$ and $E(e_{t+1}^2) = \sigma_e^2$.

2.1 Partial capital mobility under varying real interest rate

By taking logarithm of both sides, equation (1) becomes

$$\ln\left(\frac{c_{t+1}}{c_t}\right) = -\frac{1}{\alpha}\ln(1+\rho) + \frac{1}{\alpha}\ln(1+r_{t+1}) - \frac{1}{\alpha}\ln\left(1+e_{t+1}\right). \tag{2}$$

Next we take Taylor expansion of equation (2) and after some manipulation to obtain,

$$\frac{c_{t+1}}{c_t} \simeq 1 - \frac{\rho}{\alpha} + \frac{\sigma_e^2}{2\alpha} + \frac{1}{\alpha}r_{t+1} - \frac{1}{2\alpha}(r_{t+1})^2 - \frac{1}{\alpha}\left[e_{t+1} + \frac{1}{2}\sigma_e^2 - \frac{1}{2}(e_{t+1})^2\right] \tag{3}$$

Equations (2) and (3) are used for estimation.

2.2 Perfect capital mobility in a small open economy

Under the assumption of "small open economy with perfect capital mobility", the real interest rate is the same as the (fixed) world interest rate, that is, $r_t = \bar{r}, \forall t$. So, equation (1) should be $\{(1+\bar{r})/(1+\rho)\}\ c_{t+1}^{-\alpha}/c_t^{-\alpha} = 1 + e_{t+1}$. Following the same way as before, I take logarithm both sides of this equation to get,

$$\ln\left(\frac{c_{t+1}}{c_t}\right) = -\frac{1}{\alpha}\ln\left(\frac{1+\rho}{1+\bar{r}}\right) - \frac{1}{\alpha}\ln\left(1+e_{t+1}\right). \tag{4}$$

By taking Taylor expansion, we get

$$\frac{c_{t+1}}{c_t} \simeq 1 - \frac{1}{\alpha}\left(\frac{1+\rho}{1+\bar{r}} - \frac{1}{2}\sigma_e^2 - 1\right) - \frac{1}{\alpha}\ln\left(e_{t+1} + \frac{1}{2}\sigma_e^2 - \frac{1}{2}(e_{t+1})^2\right). \tag{5}$$

That is, consumption follows random walk with drift.

2.3 Complete capital immobility in an autarky

Under the assumption of completely immobile capital, domestic consumption must equal net domestic production. Hence, the trade balance equals zero ($TB_t \equiv CA_t - r_t a_t = 0$). TB_t and CA_t are trade balance and current balance, respectively. Under this condition, domestic saving is equal to domestic investment ($s_t = i_t$). Thus, $CA_t \equiv r_t a_t + (y_t - i_t - g_t) - c_t = r_t a_t$). Defining $x_t \equiv y_t - i_t - g_t$, x_t must equal c_t. Finally we can get the following relation under the complete capital immobility assumption,

$$\ln\left(\frac{c_{t+1}}{c_t}\right) = \ln\left(\frac{x_{t+1}}{x_t}\right), \tag{6}$$

and

$$\left(\frac{c_{t+1}}{c_t}\right) = \left(\frac{x_{t+1}}{x_t}\right). \tag{7}$$

3 Parameterization and Estimated Equations

From equations (2), (4), and (6), the first equation to estimate can be expressed as

$$\ln\left(\frac{c_{t+1}}{c_t}\right) = \phi_0 + \phi_1 \ln\left(1 + r_{t+1}\right) + \phi_2 \ln\left(\frac{x_{t+1}}{x_t}\right) + \ln\left(1 + e_{t+1}\right) \tag{8}$$

For perfect capital mobility (first test), the null hypothesis of Wald F test is

$$H_0: \;\; \phi_0 \neq 0,\; \phi_1 = 0,\; \phi_2 = 0.$$

For complete capital immobility (second test),

$$H_0: \;\; \phi_0 = 0,\; \phi_1 = 0,\; \phi_2 = 1.$$

From equations (3), (5), and (7), the first equation to estimate can be expressed as

$$\frac{c_{t+1}}{c_t} = \psi_0 + \psi_1 \left(r_{t+1}\right) \,+\, \psi_2 \left(r_{t+1}\right)^2 \,+\, \psi_3 \left(\frac{x_{t+1}}{x_t}\right) \,+\, \epsilon_{t+1} \tag{9}$$

For perfect capital mobility (first test), the null hypothesis of Wald F test is

$$H_0: \;\; \psi_0 \neq 0,\; \psi_1 = 0,\; \psi_2 = 0,\; \psi_3 = 0.$$

For complete capital immobility (second test),

$$H_0: \;\; \psi_0 = 0,\; \psi_1 = 0,\; \psi_2 = 0,\; \psi_3 = 1.$$

4 Data and Empirical Results

Estimations are conducted using time series (annual) data.[1] All necessary data including real interest rate can be obtained from IMF's International Financial Statistics. Data on GDP, private consumption, private investment, and government expenditure are all converted into real terms by dividing by the GDP deflator. Nominal interest rates are the call money rate for India, discount rate for Japan, monthly interbank rate for Singapore, and Federal funds rate for the US, depending on data availability. These nominal interest rates are converted into real interest rate following the method used in Mankiw[5]

$$r_t = (1-\theta)\ i_t - [(CPI_{t+1}/CPI_t) - 1],$$

where CPI is consumer price index, θ is the marginal tax rate. I set θ=0.4 following Mankiw.

The subject countries of the study include Singapore that is considered as a country with relatively free capital mobility, and India that is considered as a relatively small capital mobile economy.

4.1 Estimation of Feldstein-Horioka formula

This section tries to reassess the Feldstein-Horioka puzzle using their formula. In order to compare the results of this formula with those of my proposed formula, analyses are conducted using time series data instead of cross country data that Feldstein and Horioka used. The estimated equation is

$$\frac{I_t}{Y_t} = \alpha + \beta\ \frac{S_t}{Y_t} + \epsilon_t.$$

First I check the stationarity of each variable so as to avoid the spurious regression. Results of the augmented Dicky-Fuller (ADF)[2] test for unit root are shown in Table 1. Table 1 tells us that India and Japan have unit root for both variables, i.e., I/Y and S/Y, while, both Singapore and the US have stationary I/Y variable but non-stationary S/Y. From the results of ADF test of the first difference, I/Y and S/Y for both India and Japan are $I(1)$ stochastic process, while, I/Y is $I(0)$ and S/Y is $I(1)$ for Singapore and the US.

Next I try Johansen's cointegration test to India and Japan who have the same order of integration. The results can be seen in Table 2. From that table, we see that two variables are cointegrated with rank 1 at the 1% critical level for the cases of India and Japan.

[1]Quarterly data are available only for OECD countries. Moreover, even for OECD countries quarterly GDP deflators are rarely available.

[2]ADF test with a trend and with lag length of 1 is used throughout this paper.

Table 1: Unit Root (ADF) Test

Country	Period	I/Y	S/Y
Level			
India	1956-97	-1.325	-1.521
Japan	1956-97	-1.915	-2.179
Singapore	1960-97	-3.082^{*a}	-1.217
USA	1957-98	-2.999^{*}	-0.281
First Difference			
India	1956-97	-8.772^{**b}	-8.020^{**}
Japan	1956-97	-5.290^{**}	-3.970^{**}
Singapore	1960-97		-3.981^{**}
USA	1957-98		-5.734^{**}

[a]∗ indicates that the null hypothesis can be rejected at 5 % MacKinnon critical value.

[b]∗∗ indicates that the null hypothesis can be rejected at 1 % MacKinon critical value.

Table 2: Cointegration Test

Country	Rank	Likelihood Ratio	5% [a]	1%
India	r=0	20.006	18.17	23.46
	r=1	5.335	3.74	6.40
Japan	r=0	21.316	18.17	23.46
	r=1	6.298	3.74	6.40

[a]Johansen's cointegration test with quadratic trend and intercept

Table 3 shows the results of Feldstein-Horioka formula by using various estimation methods. Although only India and Japan have integrated variables of the same order and they are cointegrated, results of Singapore and the US are also shown in the table. Since all equations and all estimation methods show the possibility of autocorrelation, remedy (Cochran-Orcutt procedure) for it is applied in all cases. Except the case of instrumental variable method with autocorrelation remedy for the US, other cases do not show the possibility of the existence of heteroscedasticity. For the US case, I applied the ARCH model.

For India and Japan, estimated coefficient of β in every case shows expected sign and is different from zero with high statistical significance. On the other hand, although Singapore and the US regressions may be spurious, many cases of them show opposite signs with low t-values. From the results of India and Japan, we can only say that βs are statistically different from zero as well as from unity from the Wald statistics. However, we can not say about the degree of the capital mobility of these countries.

One reason of this absence of information about the degree of capital mobility that Feldstein-Horioka formula can provide is that a variety of shocks may induce a positive correlation between the two. A persistent productivity shock would raise savings because wages are temporarily high, but would also raise investment since capital is more productive.

4.2 Estimation of capital mobility under varying real interest rate

Next I estimate equation (8). Before conducting regression analyses, I check the stationarity of relevant variables. ADF test results are shown in Table 4. In cases of India and the US two variables are $I(0)$ and the other is $I(1)$. While in case of Japan, three variables have unit roots and hence can be cointegrated. For the case of Singapore all variable are $I(0)$ so we can apply OLS in level terms.

For only Japan's case we need to check cointegration. The result is shown in Table 5. From that table, we can say that three variables are cointegrated with rank 1 if 5% critical level is chosen and are cointegrated with rank 2 if 1% critical level is chosen. Hence if we estimate it in level terms the result will not be spurious.

Table 6 shows the results of estimation of equation (8). "First Test" and "Second Test" indicate the null hypotheses described in the previous subsection. In other words, if we can reject the "First Test", we may say that the country is *not perfect capital mobile country*, while if we can reject the "Second Test", we may say that the country is *not complete capital immobile country*. It is possible to have both high test values that means the country is neither perfect capital mobile nor complete capital immobile country. Furthermore, we can gauge the degree of capital mobility by comparing the estimated values of ϕ_2.

Table 3: Results of Feldstein-Horioka Formula

Country	Method	$\hat{\beta}^a$	$\bar{R}^2$	F-stat[b]	D-W	White F	J-stat
India	OLS & AR(1)	0.720 (13.035)**	.946	351.69	2.062	0.040	
	IV[c]& AR(1)	0.648 (11.677)**	.944	282.42	1.998	0.313	
	GMM[d] & AR(1)	0.649 (16.303)**	.944		2.032		.00196
Japan	OLS & AR(1)	1.454 (8.535)**	.875	140.58	2.037	2.121	
	IV & AR(1)	1.829 (4.427)**	.860	103.32	1.975	0.613	
	GMM & AR(1)	2.085 (5.079)**	.83		1.773		.0424
Singapore	OLS & AR(1)	0.152 (0.569)	.891	147.92	2.146	1.595	
	IV & AR(1)	-1.124 (-1.056)	.829	94.76	1.699	2.001	
	GMM & AR(1)	-1.124 (-1.165)	.829		1.696		.00469
USA	OLS & AR(1)	1.176 (6.388)**	.636	35.929	1.514	0.897	
	IV & AR(1)	-0.105 (-0.395)	.312	11.770	1.802	3.067 [e]	
	GMM & AR(1)	-0.108 (-0.573)	.310		1.802		.00003
	ARCH & AR(1)	1.118 (6.022)**	.603	13.168	1.506		

[a]t-values are in the parentheses showing $**$ siginificant at 1 % level and $*$ significant at the 5% level respectively for the two sided test

[b]All F-values show that the null hypothesis can be rejected at less than 1 % level

[c]Instrumental variables are one year lagged of I/Y and S/Y, constant and the real government expenditure.

[d]Same as c.

[e]Null hypothesis of no heteroscedasticity can be rejected at 6 % significant level.

Table 4: Unit Root (ADF) Test

Country	Period	$\ln(c_{t+1}/c_t)$	$\ln(1+r_{t+1})$	$\ln(x_{t+1}/x_t)$
Level				
India	1956-97	-7.647^{***a}	-2.454	-6.655^{***}
Japan	1956-97	-1.440	-0.860	-2.562
Singapore	1972-97	-3.3114^{**}	-2.769^{*}	-3.949^{***}
USA	1957-98	-4.192^{***}	-2.519	-4.713^{***}
First Difference				
India	1956-97		-6.321^{***}	
Japan	1956-97	-8.062^{***}	-5.206^{***}	-7.149^{***}
Singapore	1972-97			
USA	1957-98		-5.008^{***}	

[a] $***, *$ indicate that the null hypothesis can be rejected at 1 % and 10 % MacKinnon critical value respectively.

Table 5: Cointegration Test

Country	Rank	Likelihood Ratio	5% [a]	1%
Japan	r=0	48.079	34.55	40.49
	r=1	18.774	18.17	23.46
	r=2	3.446	3.74	6.40

[a] Johansen's cointegration test with quadratic trend and intercept

Very interesting results are found in Table 6. Comparing the results of India and Singapore, we observe that India is definitely not a perfect capital mobility country, but we cannot reject the hypothesis that India is a complete capital immobile country. On the other hand, we can strongly reject the hypothesis that Singapore is a complete capital immobile country, but we cannot reject the hypothesis that the country is a perfect capital mobile economy. Furthermore, comparing the size of the estimated values of ϕ_2, we see that India's values are close to 1, while Singapore's values rang from .17 to .3 which are very small.

Finally we estimate equation (9). As in the previous subsections, stationarity of the variables is checked first. We see from Table 7 that in the case of India "First Test" and "Second Test" express the same null hypotheses as the previous tests.

The results of ADF unit root test in Table 7 show that none of the variables of India and Singapore has unit root, meaning that we can apply OLS in levels without worrying about the spurious regression. However, for Japan and the US some variables are $I(0)$, while the others are $I(1)$, indicating the possibility of spurious regressions. Hence without proceeding cointegration test, we can use level data of India and Singapore.

Table 8 contains the results from estimation for India and Singapore. "First Test" for two countries tells us with high level of statistical significance that India is not a perfect capital mobile country, and that Singapore can be a perfect capital mobile country. On the other hand, two cases of three results in "Second Test" indicate with extremely high statistical significance the reverse possibility, that is, India can be a complete capital immobile country, while Singapore is not a complete capital immobile country.

5 Concluding Remarks

This short paper examines the degree of international capital mobility and resolves Feldstein- Horioka puzzle by developing a new method incorporating a varying real interest rate. After careful observation of the variables' stationarity, I find clear results showing that India can be called a completely capital immobile country while Singapore a perfect capital mobile country for the observed period. Furthermore, if the proposed method is allows us to gauge the degree of capital mobility. Hence if large cross country data are available, we can know the absolute degree as well as relative ranking of each country's capital mobility.

Table 6: Empirical Results of the First Estimated Equation

India (1958-1997)			
	OLS & AR(1)	IV	GMM
ϕ_0	0.001	0.008	0.008
	(0.089)	(0.397)	(0.559)
ϕ_1	0.003	-0.010	-0.010
	(0.393)	(-0.677)	(-0.920)
ϕ_2	0.795	1.064	1.068
	(10.480)***	(13.064)***	(12.048)***
$\bar{R}^2$	0.837	0.772	0.770
F-stat	67.89***	85.49***	
$D-W$	2.191	2.374	2.369
White-F	0.262	0.146	
J-stat			0.0059
First Test	108.23***	85.49***	131.43***
Second Test	1.337	0.409	0.958

Singapore (1972-1997)			
	OLS	IV	GMM
ϕ_0	0.056	0.089	0.062
	(2.355)**	(2.399)**	(2.229)**
ϕ_1	-0.009	-0.034	-0.022
	(-0.586)	(-1.493)	(-1.383)
ϕ_2	0.170	0.211	0.300
	(2.179)**	(1.413)	(2.656)**
$\bar{R}^2$	0.127	0.003	-0.039
F-stat	2.826$*$	2.642*	
$D-W$	1.890	1.825	2.176
White-F	0.693	0.663	
J-stat			0.170
First Test	2.826*	2.642*	10.85***
Second Test	45.62***	5.06***	20.02***

Table 7: Unit Root (ADF) Test

Country	Period	c_{t+1}/c_t	r_{t+1}	r^2_{t+1}	x_{t+1}/x_t
Level					
India	1956-97	-9.255^{***a}	-2.646^{*}	-3.116^{**}	-8.181^{***}
Japan	1956-97	-1.427	-6.140^{***}	-2.629^{*}	-7.194^{***}
Singapore	1972-97	-3.324^{**}	-2.991^{**}	-3.252^{**}	-3.875^{***}
USA	1957-98	-4.170^{***}	-2.382	-2.816^{*}	-4.687^{***}
First Difference					
India	1956-97				
Japan	1956-97	-8.069^{***}			
Singapore	1972-97				
USA	1957-98		-4.910^{***}		

[a] $***, **, *$ indicate that the null hypothesis can be rejected at 1 %, 5 %, and 10% MacKinnon critical values respectively.

Table 8: Empirical Results of the Second Estimated Equation

India (1958-1997)			
	OLS & AR(1)	IV & AR(1)	GMM & AR(1)
ψ_0	0.190	-0.174	-0.129
	(2.468)	(-0.601)	(-0.815)
ψ_1	0.007	-0.006	0.005
	(1.068)	(-0.475)	(0.575)
ψ_2	-0.001	-0.001	-0.001
	(-1.092)	(-0.620)	(-0.830)
ψ_3	0.799	1.156	1.114
	$(11.187)^{***}$	$(4.207)^{***}$	$(7.097)^{***}$
$\bar{R}^2$	0.848	0.738	0.762
F-stat	54.54^{***}	16.84^{***}	
$D-W$	2.183	2.009	2.135
White-F	0.195	0.789	
J-stat			0.016
First Test	41.86^{***}	6.32^{***}	23.57^{***}
Second Test	2.55^{*}	0.289	1.358

Singapore (1972-1997)			
	OLS	IV	GMM
ψ_0	0.920	0.927	0.868
	$(9.497)^{***}$	$(5.225)^{***}$	$(5.524)^{***}$
ψ_1	-0.061	-0.042	-0.059
	(-0.888)	(-1.049)	$(-2.336)^{**}$
ψ_2	0.002	0.005	0.008
	(0.820)	(0.871)	$(2.222)^{**}$
ψ_3	0.156	0.197	0.262
	$(2.024)^{*}$	(1.387)	$(2.150)^{**}$
$\bar{R}^2$	0.112	-0.024	-0.370
F-stat	2.055	1.935	
$D-W$	1.824	1.821	1.859
White-F	0.533	0.386	
J-stat			0.095
First Test	2.055	1.935	6.729^{***}
Second Test	37.08^{***}	12.73^{***}	26.88^{***}

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