The Feldstein-Horioka Puzzle Revisited: A Monte Carlo Study

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Abstract: This study revisits the Feldstein-Horioka (FH) puzzle by employing a variety of asymptotically efficient cointegration estimators, and by using the critical values obtained from Monte Carlo simulations to test the hypothesis of a unit retention coefficient. This leads to a lower rejection of the null. Nevertheless, we find limited evidence supporting the FH result. There appears to be considerable heterogeneity in terms of the savings-investment association, but only 25% of the 23 OECD countries we examine (excluding the ones with negative coefficients) can be characterised as closed economies in the FH sense. Whether or not one subscribes to the FH interpretation, the FH result does not appear to be robust.

Keywords: International Capital Mobility, Feldstein-Horioka Puzzle, Cointegration, Estimators, Monte Carlo Simulations

1. INTRODUCTION

The high correlation between national savings and investment rates across OECD countries is one of the best-established facts in international economics. In their seminal cross-section study, Feldstein and Horioka (1980) (FH henceforth) interpreted this result as evidence against capital mobility. As they put it, with perfect capital mobility "there should be no relation between domestic savings and domestic investment: saving in each country responds to the worldwide opportunities for investment while investment in that country is financed by the worldwide pool of capital". In other words, there is no a priori reason to expect saving and investment to be correlated across countries, as investment rates depend on the expected real rates of return, while saving rates depend upon demographic and cultural factors and on the distribution of income.

The FH result is clearly a "puzzle" in the presence of highly integrated financial markets, which imply a considerable degree of capital mobility. The active Eurocurrency markets, the speed with which the stock market crash of 1987 was transmitted internationally, and the large flows of portfolio and direct investment from the OECD to the emerging economies, are all clear evidence of a high degree of integration of the international financial markets. Since the 1980s, widespread deregulation and information and communication technology advances have facilitated even further cross-border capital movements.

As a result, both the economic basis of the FH model and the econometric results have been questioned. Although the "puzzle" has been confirmed by a number of subsequent cross-section and time-series studies, others have cast doubt on the existence of a robustly high association between savings and investment. Besides, theoretical models have been built which can reconcile it with perfect capital mobility (see the next section).

This paper makes an empirical contribution to the literature on the FH puzzle. It focuses on the FH "result", as opposed to the FH "interpretation", [1] i.e. it examines the robustness of their findings rather than asking the question whether a high savings-investment (S-I) correlation does indeed reflect low capital mobility. We take a time-series as opposed to a cross-section approach for the

[1] See Coakley et al (1994) for this distinction.

following reasons. First, countries display considerable differences in S-I dynamics in the short run as well as in the long run. As the S-I correlation depends on the nature of the disturbances and the structure of the economy (see Finn 1990, and Baxter and Crucini 1993), there is no reason to expect the S-I relation to be the same for every country in the sample, as cross-section regressions imply. Second, the use of long-term averages of the S-I ratios leads to an upward bias in capital mobility correlations, namely a unit correlation coefficient is more likely to be found when capital flows are mutually offset across the countries included in the sample. The intertemporal approach to the balance of payments implies that the current account balance moves over time from deficits to surpluses in order to satisfy the intertemporal budget constraint (see Sinn, 1992). Third, the savings retention coefficient from a cross-section might be significantly affected by outliers, i.e. countries which are large or have a high correlation coefficient because of capital controls. Fourth, cross-section analysis is subject to sample selection bias (see, e.g., how the correlation coefficient changes in the study of Tesar (1991) when Luxembourg is excluded from the sample). Finally, cross-section results are hard to interpret, since capital mobility estimates are derived at a particular point in time, and therefore the key question of how much of an increase in saving is truly translated into domestic investment becomes difficult to answer.

What differentiates the present paper from most previous time-series investigations is the fact that we examine the robustness of the FH result across countries and across estimators under the maintained hypothesis that savings and investment are cointegrated. Furthermore, we carry out a Monte Carlo study to obtain the small-sample distributions of the t-statistics associated with the estimators under consideration, thereby using the finite-sample rather than the asymptotic critical values for hypothesis testing. Although a few researchers had used cointegration estimators which are asymptotically efficient in the sense that they correct for long-run endogeneity effects (see, e.g., Leachmann, 1991, and Mamingi, 1997), or compared the properties of some estimators (see, e.g., Jansen, 1996), no systematic and comprehensive analysis such as ours (based on the statistical features of the actual series) had been conducted to date. [2] The layout of the paper is as follows. Section 2 describes the data and reports the estimation results. Section 3 discusses the Monte Carlo simulations. Section 4 offers some concluding remarks.

2. ESTIMATION RESULTS

Our sample comprises 23 of the 25 OECD countries (16 of which were examined by FH). Yugoslavia and Turkey were excluded due to a particularly small sample. The data source is the IMF's International Financial Statistics, CD-ROM /December 1999. For the majority of the countries the sample period goes from 1948 to 1998. [3] We used annual rather than quarterly data, as the latter are often based on interpolation procedures and are subject to seasonality. Further, short-term capital movements, such as trade credits that are essentially self-reversing, should be less important at the annual frequency, thus making it more appropriate for addressing the issue of long-term capital mobility that FH had in mind.

We used gross (rather than net) saving and investment because depreciation measures are inevitably inaccurate, especially in the presence of high inflation rates. Moreover, gross variables respond to worldwide yield differentials. Gross saving was constructed subtracting private and government consumption from GNP. Gross investment was defined as gross capital fixed formation plus change in stocks. Other variable definitions are also standard.

As a first step, we carried out unit root tests, namely the Dickey-Fuller (DF), augmented Dickey-Fuller (ADF) (where the Schwartz Information Criterion (SIC) was used to determine the optimal lag length), and Phillips-Perron (PP) tests. We used the critical values reported by MacKinnon (1991). On the whole, the results (not reported) broadly confirm those of other studies, i.e. saving and investment ratios seem to be integrated of order 1: I(1). Thus, we proceeded to test for cointegration using both the Johansen (1988, 1991) methodology by

[2] Kroll (1996) and Ho (2002) both note that the power of the estimation technique is crucial, but only compare the estimates obtained using a few panel data estimators.

[3] The countries considered are the following (with the first year of the sample in brackets if different from 1948): Australia (1951), Austria, Belgium (1953), Canada, Denmark (1950), Finland (1950), France (1950), Germany (1950), Greece, Iceland (1950), Ireland, Italy (1951), Japan (1955), Luxembourg (1950), Netherlands (1950), New Zealand, Norway (1949), Portugal (1953), Spain (1954), Sweden (1950), Switzerland, UK, US.

estimating a VAR (1,1) and the two-step Engle-Granger (1987) procedure.

The results (not reported) are generally consistent with the wide consensus that savings and investment in OECD countries are cointegrated, although the evidence was fragile in the cases of Belgium, Denmark, Finland and Norway. Given the presence of unit roots and cointegration, the cointegrating coefficient between the saving and the investment rate cannot be estimated using the least squares estimator, which, though superconsistent, would not be optimal for statistical inference. This is due to the presence of nuisance parameters in the asymptotic distribution of the OLS estimator that stem from possible long-run endogeneity and serial correlation of the cointegration error (see Phillips, 1988, Phillips and Hansen, 1990). In the presence of such second order effects, an asymptotically efficient cointegration estimator should be used. In addition to the system-based maximum likelihood Johansen estimator, we used the following single-equations estimators: ADL (Autoregressive Dynamic Linear), AADL (Augmented Autoregressive Dynamic Linear), DOLS (Dynamic Ordinary Least Squares), DGLS (Dynamic Generalised Least Squares), FMLS (Fully Modified Least Squares).

We estimated the S-I coefficient (θ) using twelve estimators: the OLS, the FMLS (Standard-Andrews), the FMLS (Standard-Newey&West), the FMLS (Prewhitened-Andrews), the FMLS (Prewhitened-Newey&West), the DOLS, the DGLS, the ADL(1,2), the AADL(1,2,1), the ADL(4,4), the AADL(4,4,4) and the Johansen estimator.

The savings retention coefficient θ, its standard error and the t-statistic were obtained in order to test the hypothesis that θ =1. The average, lowest and highest estimate of the cointegrating coefficient for each country are reported in Table 1 (individual estimates for each country are available from the authors).

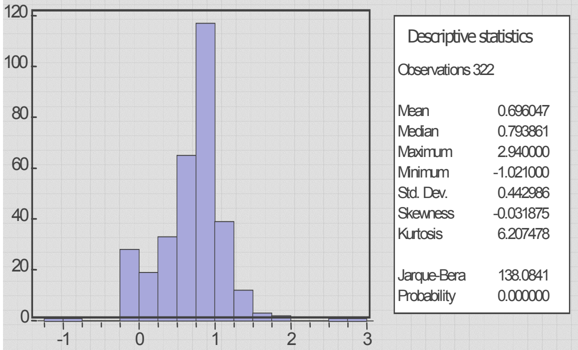
As can be seen, the average coefficients range from –0.104 to 1.319. One third of the countries have a coefficient between 0.7 and 1 (Australia, France, Greece, Iceland, Japan, Netherlands, Sweden and the UK), indicating capital immobility according to the FH interpretation, and thus representing quite closed economies. Six countries (Austria, Belgium, Canada, Denmark, Germany, Portugal, US) have average coefficients between 0 and 0.7, hence exhibiting some degree of capital mobility, with less than 70% of domestic saving being invested in the same country. Luxembourg, Norway and Spain have a negative savings retention coefficient, the first country usually being excluded from cross-section studies as an outlier due to the size of its financial and banking sector, the second because of its large industrial sector. Finally, five countries (Finland, Ireland, Italy, New Zealand and Switzerland) produced estimates over 1, indicating that investment systematically exceeds savings.

Table 1. Estimated coefficients and rejection percentages

Country	Estimation			% rejection (MonteCarlo critical values)	% rejection (asymptotic critical values)
	Average	min	max		
Australia	0.648	0.283	0.847	8%	27%
Austria	0.865	0.739	1.022	8%	45%
Belgium	0.576	0.508	0.697	58%	82%
Canada	0.566	0.268	0.802	58%	73%
Denmark	0.625	0.225	1.003	8%	18%
Finland	1.319	0.883	2.559	8%	0%
France	0.903	0.856	0.958	0%	9%
Germany	0.672	0.506	0.87	8%	55%
Greece	0.888	0.844	0.918	8%	73%
Iceland	0.938	0.724	1.136	0%	9%
Ireland	1.032	0.265	2.944	0%	27%
Italy	1.087	0.928	1.534	0%	0%
Japan	0.859	0.83	1.047	0%	0%
Luxembourg	-0.103	-0.164	-0.023	100%	100%
New Zealand	1.03	0.673	1.376	0%	9%
Netherlands	0.862	0.423	1.315	0%	9%
Norway	-0.075	-0.192	0.108	83%	100%
Portugal	0.3	0.093	0.438	8%	73%
Spain	-0.104	-1.022	0.209	42%	91%
Sweden	0.75	0.486	1.401	0%	27%
Switzerland	1.016	0.837	1.053	0%	0%
UK	0.882	0.8	0.994	0%	0%
US	0.469	0.044	1.199	67%	64%

Figure 1 shows the “distribution” and the “descriptive statistics” of the sample of estimates coefficients. On average, the FH coefficient is 0.69, although the estimates range from –1.02 to 2.94.

Figure 1



We also divided the estimates in 14 categories (see Table 2). It can be seen that over 30% of the coefficients are between 0.8 and 1, while 60% of them ranges from 0.6 to 1.2, very close to a unit coefficient.

Table 2

Distribution of Estimates				
Included observations: 322				
Number of categories: 14				
Value	Count	Percent	Cumulative Count	Cumulative Percent
[-1.2, -1)	1	0.31	1	0.31
[-1, -0.8)	1	0.31	2	0.62
[-0.2, 0)	28	8.70	30	9.32
[0, 0.2)	16	4.97	46	14.29
[0.2, 0.4)	24	7.45	70	21.74
[0.4, 0.6)	36	11.18	106	32.92
[0.6, 0.8)	57	17.70	163	50.62
[0.8, 1)	**101**	**31.37**	**264**	**81.99**
[1, 1.2)	36	11.18	300	93.17
[1.2, 1.4)	13	4.04	313	97.20
[1.4, 1.6)	5	1.55	318	98.76
[1.8, 2)	2	0.62	320	99.38
[2.4, 2.6)	1	0.31	321	99.69
[2.8, 3)	1	0.31	322	100.00
Total	322	100.00	322	100.00

In the next section we report on the Monte Carlo simulations we carried out in order to obtain the exact distribution of the estimators, so as to perform valid tests of the null hypothesis that the coefficient is equal to one.

3. MONTE CARLO SIMULATIONS

We conducted a Monte Carlo study to obtain the 2.5% and 97.5% points of the empirical distribution of the t-statistic for each estimator in each of the 23 countries. [4] This is necessary to draw valid statistical inference, as standard distributions do not apply in this case. The Data Generating Process (DGP) was assumed to be the following:

$$I_t = \theta S_t + u_{1t}$$
$$\Delta S_t = u_{2t} \text{ for } t = 1, 2, ..., T$$

where I_t and S_t are the investment and saving rate respectively, and

$u_t = (u_{1t}, u_{2t})'$ follows a VAR(1) process:
$u_t = \mathrm{A} u_{t-1} + e_t, e_t \approx Niid\ (0, \Sigma)$.

[4] GAUSS was used to carry out the experiments.

Estimates of the 2x2 A matrix, and of the variance-covariance matrix of the DGP (needed for each country) were obtained as follows. First, we estimated the FH equation and saved the residuals (u_{1t}); then we ran an AR(1) regression for S_t, also saving the residuals (u_{2t}). Using the series u_{1t} and u_{2t}, we estimated a VAR(1) and consequently the A matrix and the variance-covariance matrix. These estimates were used for the Monte Carlo simulations, and the exact distribution of each estimator for each country was obtained (details available from the authors).

It is clear that there is a shift in the empirical distributions compared to the Standard Normal. Using the critical values from the latter as a benchmark for rejection of the null hypothesis that θ=1 would have resulted in a higher percentage of rejections (see Table 1). The distributions of the estimators provided by our Monte Carlo simulations are less leptokurtic than the Standard Normal, leading to an augmented area of non-rejection. It should also be noted that the standard errors of the estimates are big, resulting in low t-statistics and non-rejection of the null hypothesis, despite the fact that the estimated coefficient is considerably lower than unity.

The percentages of rejection for each country are shown in Table 1. On the basis of these results, and adopting the FH interpretation, one would conclude that Belgium, Canada, Luxembourg, Norway, Spain and USA are countries with high capital mobility, while the rest seem to have a savings retention coefficient close to unity. More in detail, the OECD countries would be categorized as follows in terms of capital mobility:

- Austria, France, Greece, Iceland, Japan, Netherlands, Sweden and the UK display capital immobility (0.75<θ<1).
- Australia, Belgium, Canada, Denmark, and Germany display medium capital mobility (0.5<θ<0.75).
- Portugal and the United States display capital mobility (0<θ<0.5).
- Finland, Ireland, Italy, New Zealand and Switzerland have a FH coefficient greater than one.
- Luxembourg, Norway and Spain display a negative correlation between the savings and investment ratios.

The percentages of rejection per estimator using both the asymptotic critical values and the ones obtained from our Monte Carlo simulations are shown in Table 3. It is clear that the OLS estimator rejects more often than the other estimators (both by the asymptotic values and the Monte Carlo ones), while the ADL (1,2), AADL (1,2,1) and the AADL (4,4,4) accept the hypothesis that $\theta=1$ more frequently.

Table 3. Rejection percentages for each estimator

Estimator	% rejection (MonteCarlo critical values)	% rejection (asymptotic critical values)	Estimator	% rejection (MonteCarlo critical values)	% rejection (asymptotic critical values)
OLS	43%	78%	DGLS	26%	30%
FM-S-A	26%	48%	ADL (1,2)	9%	13%
FM-S-NW	30%	48%	AADL (1,2,1)	9%	13%
FM-PW-A	22%	52%	ADL (4,4)	13%	30%
FM-PW-NW	26%	48%	AADL (4,4,4)	4%	26%
DOLS	26%	52%	JOHANSEN	13%	26%

4. CONCLUSIONS

A number of papers have questioned both the FH result (i.e. the robustness of the savings-investment association), and the FH interpretation (i.e. its implying little or no capital mobility). This study has re-examined the former in a sample of 23 OECD countries adopting a time-series approach. With a few exceptions, earlier contributions had not investigated the robustness of the estimates of the retention coefficient to alternative cointegration estimation methods (apart from Jansen, 1996, who had considered a few). Also, they had not analysed the small-sample properties of the t-statistics distributions associated with the various estimators. By contrast, we have addressed both issues. First, we have employed a variety of estimators which correct for both serial correlation and long-run endogeneity to estimate the savings retention coefficient. Second, we have tested the hypothesis of a unit coefficient using the critical values obtained from Monte Carlo simulations, which replicated the statistical processes followed by the investment and saving series. This led to a lower rejection of the FH hypothesis than standard critical values would have implied.

Nevertheless, we found limited evidence supporting the FH result. There appears to be considerable heterogeneity across countries in terms of the savings-investment association, with both estimates and percentages of rejection varying substantially. Financially integrated economies such as the US yield lower estimates of the retention coefficient than countries such as Japan, where extensive capital controls were imposed (closed economies). Only 25% of the 23 OECD countries examined (excluding the ones with negative coefficients) can be characterised as closed economies in the FH sense, the others being financially open and integrated economies. Whether or not one subscribes to the FH interpretation, the FH result itself does not seem to be robust. The econometric evidence is in fact consistent with casual empiricism suggesting a higher degree of integration of international capital markets (as also argued by, *inter alia*, Coakley et al, 1994, 1995a,b, 1996).

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