

A Service of

ZBW

Leibniz-Informationszentrum Wirtschaft Leibniz Information Centre for Economics

Levy, Daniel

Working Paper Is the Feldstein-Horioka Puzzle Really a Puzzle?

Working Paper, No. 2003-02

Provided in Cooperation with: Department of Economics, Bar-Ilan University

Suggested Citation: Levy, Daniel (2003) : Is the Feldstein-Horioka Puzzle Really a Puzzle?, Working Paper, No. 2003-02, Bar-Ilan University, Department of Economics, Ramat-Gan

This Version is available at: https://hdl.handle.net/10419/259334

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.



WWW.ECONSTOR.EU

IS THE FELDSTEIN-HORIOKA PUZZLE REALLY A PUZZLE?*

Daniel Levy Bar-Ilan University and Emory University

Key Words: Capital Mobility, Investment-Saving Correlation, Dynamic Budget Constraint, Integration and Cointegration, Omitted Variables

JEL Codes: F21, F32, F02, F41

* Forthcoming in:

Advances in International Economics and Finance, edited by G. Agiomirgianakis, T. Biswas, J. Coakley, and C. Tsoukis (London: Kluwer Academic Publishers), 2003.

IS THE FELDSTEIN-HORIOKA PUZZLE REALLY A PUZZLE?*

Abstract

Using the framework of a dynamic intertemporal optimization model of an open economy, it is shown that the long-run investment-saving correlation follows directly from the economy's dynamic budget constraint and this does not depend on the degree of international capital mobility. Therefore, unless the budget constraint is violated, the time series of investment and saving should be cointegrated, and this should be true for any degree of capital mobility. Using an improved econometric technique, which encompasses the tests used by previous authors and avoids some of the pitfalls associated with their tests, I show that their conflicting findings can be explained by a simple but important, omitted variables problem. Using annual and quarterly post-war U.S. data, I find that investment and saving are cointegrated in levels as well as in rates, regardless of the time period considered, as predicted by the model.

1. INTRODUCTION

There is strong empirical evidence that domestic investment (I) and national saving (S) are correlated.¹ Much of the evidence is based on cross-section regressions of multi-year average data and therefore, this is considered to be a long-run phenomenon. This finding, also known as the Feldstein-Horioka (1980) puzzle, has received significant attention because Feldstein and Horioka interpret it as evidence of low international capital mobility. In a closed economy, investment must be financed by saving. In an open economy, however, some of the investment may be financed by foreign saving and therefore, saving and investment could move independently from each other. Thus, the high *I-S* correlation, Feldstein and Horioka argue, suggests that capital might not be mobile. This conclusion, however, is in contrast with the deregulation of capital markets and increased integration of world financial markets in the last 30 years. Also, studies measuring capital mobility directly using PPP and various interest parity conditions, conclude that capital is very mobile.²

Knowing the true degree of capital mobility is important for several reasons. For example, the effect of fiscal policy crucially depends on the extent of capital mobility. In addition, an economy's access to capital markets can reduce the cost of adjustment to external shocks. Also, capital mobility determines the rate at which incomes converge. Further, perfect capital mobility is often assumed to hold in macroeconomic models. Capital immobility would call into question this common practice.³

The existing time series studies of *I-S* comovement report conflicting results. For example, Miller (1988) finds that saving and investment in the US are cointegrated during the fixed, but not during the flexible exchange-rate period, and concludes that increased capital mobility since the 1970s may have severed the *I-S* link. Gulley (1992) uses an improved test and finds that saving and investment are not cointegrated in either period. Otto and Wirjanto (1989) also conclude that saving and investment in the U.S. are not cointegrated. Alyousha and Tsoukis (in this volume) use data that cover a longer time horizon but they also find no cointegration.

This chapter claims that there is nothing puzzling in the Feldstein and Horioka's finding. The neoclassical growth model predicts that, in the steady state, investment and saving would be proportional to output.⁴ It would be puzzling, therefore, if we did *not* find high *I-S* correlation.⁵

Most optimization-based dynamic models of open economy also predict that investment and saving should be correlated in the long run. Optimizing individuals face intertemporal budget constraint, which implies that, in the long run, current account balances should add up to zero as current account surpluses or deficits cannot be sustained forever. Thus, in the long run, investment and saving would be correlated, regardless of the degree of capital mobility, as long as the intertemporal budget constraint is not violated. A test of *I-S* cointegration, therefore, is merely a test of country's economic solvency.

It follows that the time series of investment and saving should be cointegrated, and this would be true for any degree of capital mobility. Using an improved econometric technique which encompasses the tests used by the above authors and avoids some of the pitfalls associated with their tests, I show that their conflicting findings can be explained by a simple, but important, omitted variables problem. In particular, using annual and quarterly post-war U.S. data, I demonstrate that even if investment and saving are not cointegrated in a bivariate setup, they are cointegrated when output is added to the system. In order to allow for the possibility of structural breaks in the *I-S* relationship, I consider the entire post-war sample period as well as its several sub-periods. It turns out that the cointegration finding is robust regardless of the time period considered.

Thus, the U.S. data do not violate the intertemporal budget constraint and so the U.S. economy is solvent. The main conclusion is that the observed long-run *I-S* correlation cannot be useful in measuring the degree of long-term capital mobility.

The chapter is organized as follows. In the next section I derive the long-run implication of the intertemporal budget constraint of an open economy and discuss its interpretation in the context of the empirical findings reported below. In section 3, I discuss omitted variables problem in cointegration tests. In section 4, I discuss the integration tests and present their results. The cointegration test results are reported in section 5. The paper ends with a brief summary and concluding remarks in section 6.

2. INTERTEMPORAL BUDGET CONSTRAINT

Consider a dynamic optimization model of an open economy with a budget

constraint of the form:

$$\frac{dB_t}{dt} = \rho_t B_t + C_t + G_t + I_t - Y_t, \qquad (1)$$

where ρ is time varying world interest rate, *B* is foreign debt, *C* is consumption, *G* is government expenditure, *I* is investment, and *Y* is output. According to (1), the change in foreign debt equals spending minus production, where spending includes interest payments on the existing debt. The idea behind this constraint is that an economy may borrow from abroad to pay for excess spending, or it may lend to a foreign country to accommodate excess production. Thus, world capital markets enable the economy to accommodate temporary imbalances between production and spending.

It is well known that the intertemporal budget constraint given in (1) is actually a nonhomogenous differential equation. Integrating forward yields:

$$B_{t} = A\psi_{t}^{-1} + \psi_{t}^{-1} \int_{t}^{\infty} \psi_{s} \left(Y_{s} - C_{s} - G_{s} - I_{s}\right) ds, \qquad (2)$$

where A is set to zero, and $\ln \psi_t = -\int_0^t \rho_s ds$, where ψ_t is the discount factor applied to the returns of the time *t*-period into the future. In a similar fashion,

$$\ln \psi_s = -\int_0^s \rho_v dv = -\int_t^{t+s} \rho_v dv,$$

which is used in deriving (2). The discount factor $\psi_t^{-1}\psi_s$ gives the time *t*-value of a dollar to be delivered at time *s*.

Now let us assume that the

$$\lim_{t\to\infty}(\psi_t B_t)=0,$$

which is the non-Ponzi game condition. This prevents the representative agent from incurring ever-increasing debt by continuously borrowing without a limit. At the same time, however, the assumption does not impede the agent's ability to incur a temporary debt to accommodate temporary imbalance between production and spending.

The above budget constraint can be used to relate the long-run *I-S* comovement to current account stationarity. Assume $\rho_s = \rho, \forall s$. Then ψ_t becomes the standard continuous-time discount factor with constant interest rate,

$$\ln \psi_t = -\int_0^t \rho \, ds = -\rho t \, .$$

In this case (2) can be rewritten as:

$$e^{-\rho t}B_{t} = \int_{t}^{\infty} e^{-\rho s} \left(Y_{s} - C_{s} - G_{s} - I_{s}\right) ds, \qquad (3)$$

which, using the fact that

$$e^{-\rho t} = \int_t^\infty \rho e^{-\rho s} ds ,$$

can be further rewritten as

$$\int_{t}^{\infty} e^{-\rho s} \left(Y_{s} - \rho B_{s} - C_{s} - G_{s} - I_{s} \right) ds = 0, \qquad (4)$$

where $Y_s - \rho B_s$ denotes the net income of domestic residents, the *GNP*. But $S = GNP - C - G = Y - \rho B - C - G$, which follows from the national income accounting. Therefore, in (4), the term in parentheses equals S - I, which in turn equals the current-account deficit.

Thus, a long-run *I-S* correlation is equivalent to a stationarity of current account deficit. Therefore, if investment and saving are cointegrated, it is an indicator of the country's economic solvency. As Obstfeld (1991), Alyousha and Tsoukis (in this volume) and Coakley, et al. (1996) emphasize, in a model with a variable real interest rate, stationarity of current account is sufficient for external solvency. The implication

of (4), however, is that in a model with a constant real interest rate, stationarity of current account is both necessary and sufficient for economic solvency.

3. OMITTED VARIABLES IN COINTEGRATION

Since investment and saving tend to be non-stationary, Miller (1988), Otto and Wirjanto (1989), and Gulley (1992) use the cointegration methodology to study the *I-S* relationship in the post-war U.S. All three use Engle and Granger's (1987) two-step estimation method, but report conflicting findings. Miller (1988) finds that the series are cointegrated prior to 1971, during the fixed exchange rate period, but not after 1971, during the fixed exchange rate period, but not after 1971, however, find that the series are not cointegrated in either period.

Because investment and saving must be cointegrated, these conflicting findings may be due to an omitted variable. Consider a situation where y, x_1 , and x_2 are all I(1), but their linear combination is I(0). In other words, I assume that the time series of y, x_1 , and x_2 are cointegrated, which means that $y = \beta_1 x_1 + \beta_2 x_2 + \varepsilon$, where $\varepsilon \sim I(0)$. Now, suppose that that we inadvertently omit x_2 and run $y = \beta_1 x_1 + \mu$. Since $\mu = (\beta_2 x_2 + \varepsilon) \sim I(1)$, we would mistakenly conclude that y and x_1 are not cointegrated.

This example suggests the possibility that the conflicting results reported in the above studies may be caused by omission of some important variable. According to the neoclassical growth model, a natural candidate for a missing variable is output because in that model, investment and saving are proportional to output.

4. INTEGRATION TEST RESULTS

To test for stationarity, Miller (1988) uses the Augmented Dickey-Fuller (ADF) unit root test:

$$\Delta x_t = \gamma x_{t-1} + \sum_{i=1}^{4} \phi_i \Delta x_{t-i} + \varepsilon_t$$
(5)

However, Gulley (1992) correctly claims that the exclusion of the constant is appropriate only if the mean of the series is zero, which is not the case for saving or investment. Therefore he modifies (5) by adding a constant,

$$\Delta x_t = \alpha_1 + \gamma x_{t-1} + \sum_{i=1}^4 \phi_i \Delta x_{t-i} + \varepsilon_t$$
(6)

and tests for $\gamma = 0$.

However, this version of the ADF test is not problem-free either. The reason is that the tabulated distribution of the unit root test statistic for version (6) depends crucially on the assumption that $\alpha_1 = 0$. That is, it has the Dickey-Fuller distribution only when there is no drift term in the data-generating process of x_t . If the true $\alpha_1 \neq 0$, then the statistic for testing the null hypothesis $\gamma = 0$ is asymptotically distributed as N(0,1), and, in finite samples, its distribution may or may not be well approximated by the Dickey-Fuller distribution.⁶ Therefore, if the drift parameters in the data-generating processes of investment and saving are non-zero, then using version (6) of the test is inappropriate.

To avoid the dependence of the distribution of the test statistic on the value of α_1 , MacKinnon (1991) suggests adding a linear time trend to (6),

$$\Delta x_{t} = \alpha_{0} t + \alpha_{1} + \gamma x_{t-1} + \sum_{i=1}^{4} \phi_{i} \Delta x_{t-i} + \varepsilon_{t}, \qquad (7)$$

under the assumption that there is no trend in the data-generating process.

Insert Figure 1 here

I use (7) to examine the unit-root properties of the time series of saving, investment, and output. Along with (7), I have used Box-Pierce, Ljung-Box, and Lagrange Multiplier tests (not shown to save space) to verify that the error terms in the unit-root test regressions are not serially correlated.

Insert Figure 2 here

I use quarterly and annual data for 1947–1987. The quarterly data are identical to those used by Miller (1988), Otto and Wirjanto (1989), and Gulley (1992). I study the *I*-*S* relationship both, in levels and in rates.⁷

Insert Figure 3 here

The source of the data on national saving, domestic investment, and output is the US-NIPA Tables of the Bureau of Economic Analysis.

Insert Figure 4 here

In addition to the entire sample period 1947:1–87:3, I also examine its three subperiods, 1947:1–71:2, 1971:3–87:3, and 1980:1–87:3.

Table 1. Unit-Root ADF Test of Investment, Saving, and Output: Annual Data

Period	Series	Level	First Difference (Δ)
1947-87	Ι	-1.47	-3.57**
(n = 41)	S	-1.59	-3.71
	Y	-1.22	-4.01**
	I/Y	-3.53**	
	S/Y	-3.38**	

Notes: Superscripts *, **, and *** in all tables indicate statistical significance at 1%, 5%, and 10%, respectively. The corresponding MacKinnon (1991) critical values for the ADF test statistics are -4.19, -3.52, and -3.19, respectively. Miller (1988), Otto and Wirjanto (1989), and Gulley (1992) do not use annual data.

The 1947:1–87:3 sample period was chosen to match the sample periods used by Miller (1988), Otto and Wirjanto (1989), and Gulley (1992).⁸

					L	evy
Period	Series	Miller	Otto and	Gulley		
			Wirjanto		Level	Difference
1947:1-87:3	Ι		-3.98**	-0.86	-3.33	-6.87*
(<i>n</i> = 163)	S		-3.83**	-1.28	-3.40	-6.90*
	Y				-2.03	-5.51*
	I/Y	-0.14		-4.88**	-3.77**	
	S/Y	-0.77		-3.09**	-3.75**	
1947:1-71:2	Ι		-3.54**	-0.46	-3.22	-5.48*
(n = 98)	S		-2.54	-0.37	-3.41	-5.19*
	Y				-1.35	-4.48*
	I/Y	-0.04		-3.91**	-4.25*	
	S/Y	-0.40		-3.30**	-4.11*	
1971:3-87:3	Ι		-3.11	-1.94	-2.66	-4.39*
(n = 65)	S		-3.25	-2.78	-2.76	-4.49*
	Y				-2.43	-3.32***
	I/Y	-0.37		-3.00**	-2.43	-4.43*
	S/Y	-0.74		-1.22	-2.58	-4.44*
1980:1-87:3	Ι				-2.99	-3.57**
(n = 31)	S				-2.67	-3.63**
	Y				-1.75	-2.73
	I/Y				-3.53***	-3.70**
	S/Y				-3.16	-3.70**

Table 2. Unit-Root ADF Tests of Investment, Saving, and Output: Quarterly Data

The first two sub-periods, 1947:1–71:2 and 1971:3–87:3, correspond to the fixed and flexible exchange rate regimes, respectively.⁹ The last sub-period, 1980:1–87:3, is examined to see whether the large capital inflow into the U.S. during the Reagan administration altered the *I-S* relationship.

The annual series measured in levels (log) and as a fraction of output (that is, the investment and saving rates) are displayed in Figures 1 and 2, respectively. Similarly,

Notes: The corresponding critical values of MacKinnon (1991) for Levy's ADF test statistics are -4.01, -3.43, and -3.14 for 1947:1–87:3, -4.05, -3.45, and -3.15 for 1947:1–71:2, -4.10, -3.47, and -3.16 for 1971:3–87:3, and -4.28, -3.56, and -3.21 for 1980:1–87:3, respectively. Otto and Wirjanto's (1989) sample begins with 1956:1. The ADF statistic values for Miller (1988), Otto and Wirjanto (1989), and Gulley (1992) are taken from the respective studies.

the quarterly series measured in levels (log) and as a fraction of output are shown in Figures 3 and 4, respectively.

I present the integration test results in Tables 1 and 2. The ADF test statistics indicate that the *S*, *I*, and *Y* series are I(1) when measured in levels. When differenced, all three series appear to be I(0). This is true for both the annual (Table 1) as well as the quarterly data (Table 2). When measured in rates, saving and investment appear to be I(1) during the 1971:3–87:3 and 1980:1–87:3 periods.¹⁰ In what follows, therefore, I treat them as I(1).

5. COINTEGRATION TEST RESULTS

I use Johansen's (1988) maximum likelihood (ML) method, which is superior to the Engle-Granger (1987) two-step method used by the above authors. In addition to the inferior statistical properties of its estimators, the Engle-Granger method has the disadvantage that for estimating a cointegration relationship, some kind of normalization is necessary. Practical applications have shown that the results can be very sensitive to the normalization chosen. Johansen's method treats all variables as endogenous, thereby avoiding the problem of choosing a normalization altogether.

Johansen (1988) offers two tests for estimating the number of cointegrating vectors. The first is called *maximal eigenvalue test*, and is given by the test statistic

$$\lambda_{\max} = -n\log(1-\hat{\lambda}_r),$$

where *n* is the number of observations, and $\hat{\lambda}_r$ is the *r*th eigenvalue to be determined by solving the determinantal equation associated with the residual product moment matrix constructed using the residuals' matrices.

The maximal eigenvalue test is designed to test H(r-1) against H(r). That is, the null hypothesis is that there are (r-1) cointegrating vectors against the alternative r.

The second test, called the *trace test*, is designed to test the null H(r) against the alternative H(m), where r < m. The trace test statistic is given by

$$J_T = -n \sum_{i=r+1}^m \log(1 - \hat{\lambda}_i).$$

The cointegration test results are presented in Tables 3–7. In estimating the cointegration vectors, I used VAR(4). It is not known a priori whether the true datagenerating process contains a deterministic trend or not. I, therefore, conduct the cointegration tests under both options. The test statistics are identical under both assumptions; only the critical values differ.

Variables	Test	H_0	H_1	Test	Critical Value			
				Statistic	Trend i	n DGP	No Trend in DG	
					95%	90%	95%	90%
<i>I</i> , <i>S</i>	λ_{\max}	r = 0	<i>r</i> = 1	6.56	14.06	12.07	14.90	12.91
		$r \leq 1$	r = 2	1.69	3.76	2.68	8.17	6.50
	J_T	r = 0	$r \ge 1$	8.26	15.41	13.32	17.95	15.66
		$r \leq 1$	r = 2	1.69	3.76	2.68	8.17	6.50
<i>I</i> , <i>S</i> , <i>Y</i>	$\lambda_{ m max}$	r = 0	<i>r</i> = 1	20.18***	20.96	18.59	21.07	18.90
		$r \leq 1$	r = 2	6.23	14.06	12.07	14.90	12.91
		$r \leq 2$	r = 3	2.97	3.76	2.68	8.17	6.50
	J_T	r = 0	$r \ge 1$	29.39***	29.68	26.78	31.52	28.70
		$r \leq 1$	$r \ge 2$	9.20	15.41	13.32	17.95	15.66
		$r \leq 2$	r = 3	2.97	3.76	2.68	8.17	6.50

Table 3. Cointegration Test: Annual Data, 1947-87 (n = 41)

Note: The critical values reported in all cointegration test tables are taken from Osterwald-Lenum (1992).

In Johansen's framework the number of cointegrating vectors is determined sequentially. We start with the hypothesis that there are no cointegrating relations, that is, r = 0, where *r* denotes the number of cointegrating relationships. We continue only if this hypothesis is rejected.

Variables	Test	H_0	H_1	Test		Critical Value		
				Statistic	Trend	in DGP	No Trend	in DGP
				_	95%	90%	95%	90%
<i>I</i> , <i>S</i>	λ_{\max}	r = 0	<i>r</i> = 1	18.58**	14.06	12.07	14.90	12.91
		$r \leq 1$	r = 2	2.39	3.76	2.68	8.17	6.50
	J_T	r = 0	$r \ge 1$	20.97**	15.41	13.32	17.95	15.66
		$r \leq 1$	r = 2	2.39	3.76	2.68	8.17	6.50
I, S, Y	λ_{\max}	r = 0	r = 1	27.05	20.96	18.59	21.07	18.90
		$r \leq 1$	r = 2	8.66	14.06	12.07	14.90	12.91
		$r \leq 2$	r = 3	5.79	3.76	2.68	8.17	6.50
	J_T	r = 0	$r \ge 1$	41.51**	29.68	26.78	31.52	28.70
		$r \leq 1$	$r \ge 2$	14.46	15.41	13.32	17.95	15.66
		$r \leq 2$	<i>r</i> = 3	5.79	3.76	2.68	8.17	6.50

Table 4. Cointegration Test: Quarterly Data, 1947:1-87:3 (n = 163)

In this case, we test the hypothesis that there is at most one cointegrating vector, $r \le 1$, and so on. The test results can be interpreted in favor of cointegration only if 0 < r < m, where *m* is the number of variables in \mathbf{x}_t .

<i>Table 5</i> . Cointegration	Test: Quarterly	/ Data, 1947:1·	-71:2 (n = 98)
U	<pre></pre>		

Variables	Test	H_0	H_1	Test		Critical Value			
				Statistic	Trend i	n DGP	No Tren	d in DGP	
					95%	90%	95%	90%	
<i>I</i> , <i>S</i>	$\lambda_{\rm max}$	r = 0	<i>r</i> = 1	9.45	14.06	12.07	14.90	12.91	
		$r \leq 1$	r = 2	0.82	3.76	2.68	8.17	6.50	
	J_T	r = 0	$r \ge 1$	10.28	15.41	13.32	17.95	15.66	
		$r \leq 1$	r = 2	0.82	3.76	2.68	8.17	6.50	
<i>I</i> , <i>S</i> , <i>Y</i>	λ_{\max}	r = 0	r = 1	32.08	20.96	18.59	21.07	18.90	
		$r \leq 1$	r = 2	10.49	14.06	12.07	14.90	12.91	
		$r \leq 2$	r = 3	0.02	3.76	2.68	8.17	6.50	
	J_T	r = 0	$r \ge 1$	42.60**	29.68	26.78	31.52	28.70	
		$r \leq 1$	$r \ge 2$	10.52	15.41	13.32	17.95	15.66	
		$r \leq 2$	<i>r</i> = 3	0.02	3.76	2.68	8.17	6.50	

Full rank, that is r = m, only indicates that the data vector process \mathbf{x}_t is stationary. If r = 0, then the matrix $\mathbf{\Pi}$, which is the matrix of the coefficients on the variables \mathbf{x}_{t-p} in the first-differenced VAR model, is the null matrix. In that case, the model becomes a traditional differenced VAR system.

Variables	Test	H_0	H_1	Test	Critical Value				
				Statistic	Trend in	n DGP	No Trend	in DGP	
				-	95%	90%	95%	90%	
<i>I</i> , <i>S</i>	λ_{\max}	r = 0	<i>r</i> = 1	19.44**	14.06	12.07	14.90	12.91	
		$r \leq 1$	r = 2	4.91	3.76	2.68	8.17	6.50	
	J_T	r = 0	$r \ge 1$	24.35**	15.41	13.32	17.95	15.66	
		$r \leq 1$	r = 2	4.91	3.76	2.68	8.17	6.50	
<i>I</i> , <i>S</i> , <i>Y</i>	$\lambda_{ m max}$	r = 0	r = 1	22.39	20.96	18.59	21.07	18.90	
		$r \leq 1$	r = 2	7.24	14.06	12.07	14.90	12.91	
		$r \leq 2$	r = 3	4.21	3.76	2.68	8.17	6.50	
	J_T	r = 0	$r \ge 1$	33.85**	29.68	26.78	31.52	28.70	
		$r \leq 1$	$r \ge 2$	11.45	15.41	13.32	17.95	15.66	
		$r \leq 2$	r = 3	4.21	3.76	2.68	8.17	6.50	
I/Y, S/Y	$\lambda_{ m max}$	r = 0	r = 1	15.09	14.06	12.07	14.90	12.91	
		$r \leq 1$	r = 2	1.84	3.76	2.68	8.17	6.50	
	J_T	r = 0	$r \ge 1$	16.93**	15.41	13.32	17.95	15.66	
		$r \leq 1$	$r \ge 2$	1.84	3.76	2.68	8.17	6.50	

Table 6. Cointegration Test: Quarterly Data, 1971:3–87:3 (n = 65))
---	---

In the bivariate setting, I find that for the annual data (see Table 3), the null of no cointegration cannot be rejected.

For the quarterly data, *I-S* levels are cointegrated during the 1947:1–87:3 period (see Table 4) as well as during the 1947:1–71:2 period (see Table 5). For the 1971:3–87:3 period, the results are inconclusive because with-trend specification of the test

indicates one cointegrating vector but no-trend specification indicates stationarity.

When measured in rates (see Table 6), both test statistics indicate *I-S* cointegration with one cointegrating vector.¹¹ For the 1980:1–87:3 period, the results support *I-S* cointegration: with no-trend specification, the null of one cointegration vector cannot be rejected. The with-trend cointegration test indicates that the null can be rejected only at 10% significance, but not at 5% significance.

When the variables are measured in rates, I find that during 1971:3–87:3 (see Table 6) and 1980:1–87:3 (see Table 7), both test statistics uniformly reject the null of zero cointegrating vectors in favor of one cointegrating vector. Thus, investment and saving during these periods are cointegrated.

In sum, the bivariate *I-S* cointegration tests are somewhat mixed, although in general they indicate a cointegration if quarterly data are used.

In the trivariate system with *I*, *S*, and *Y*, the results indicate that the three series are cointegrated with one cointegrating vector. This finding holds for all sample periods considered and for both test statistics used (see Tables 4–7). Here we find a cointegration using the annual data also (see Table 3).

Variables	Test	H_0	H_1	Test		Critical Value			
				Statistic	Trend in	n DGP	No Trend	l in DGP	
					95%	90%	95%	90%	
I, S	λ_{\max}	r = 0	<i>r</i> = 1	17.48**	14.06	12.07	14.90	12.91	
		$r \leq 1$	r = 2	3.08	3.76	2.68	8.17	6.50	
	J_T	r = 0	$r \ge 1$	20.57**	15.41	13.32	17.95	15.66	
		$r \leq 1$	r = 2	3.08	3.76	2.68	8.17	6.50	
<i>I</i> , <i>S</i> , <i>Y</i>	λ_{\max}	r = 0	<i>r</i> = 1	27.2 <u>3</u>	20.96	18.59	21.07	18.90	
		$r \leq 1$	r = 2	11.84	14.06	12.07	14.90	12.91	
		$r \leq 2$	r = 3	1.80	3.76	2.68	8.17	6.50	
	J_T	r = 0	$r \ge 1$	40.88**	29.68	26.78	31.52	28.70	
		$r \leq 1$	$r \ge 2$	13.65	15.41	13.32	17.95	15.66	
		$r \leq 2$	r = 3	1.80	3.76	2.68	8.17	6.50	
I/Y, S/Y	λ_{\max}	r = 0	<i>r</i> = 1	20.34	14.06	12.07	14.90	12.91	
		$r \leq 1$	r = 2	1.29	3.76	2.68	8.17	6.50	
	J_T	r = 0	$r \ge 1$	21.64**	15.41	13.32	17.95	15.66	
		$r \leq 1$	$r \ge 2$	1.29	3.76	2.68	8.17	6.50	

Table 7. Cointegration Test: Quarterly Data, 1980:1–87:3 (n = 31)

This means that the time series of investment and saving are indeed cointegrated, as predicted by the theoretical arguments made in section 2.

The estimated cointegrating vectors and the corresponding adjustment matrices of the cointegration relationships found are reported in Table 8. The long-run coefficient on saving shows remarkable stability with the exception of the annual data, where the estimated coefficient is a little bit higher.¹²

Further, according to the figures reported in Table 8, the homogeneity restrictions seem to be satisfied by the data. For example, in the bivariate regressions, the coefficient on saving is close to 1 whether the regression is run in levels or rates.

		Cointe	grating	Vectors			Adjust	ment M	latrixes	
Sample	Ι	S	Y	I/Y	S/Y	Ι	S	Y	I/Y	S/Y
1947-87	-1.00	1.19	-0.09			-0.18	-0.33	-0.63		
1947:1-87:3	-1.00	1.00				-0.11	-0.46			
1947:1-87:3	-1.00	1.14	-0.03			-0.27	-0.48	-0.45		
1947:1-71:2	-1.00	1.06	0.14			0.46	0.42	0.21		
1971:3-87:3	-1.00	1.11				-0.80	-1.08			
1971:3-87:3	-1.00	1.14	-0.01			-0.41	-0.70	-0.89		
1971:3-87:3				-1.00	1.06				-0.36	-0.77
1980:1-87:3	-1.00	1.10				-2.87	-3.22			
1980:1-87:3	-1.00	1.05	-0.01			-2.25	-3.39	-2.88		
1980:1-87:3				-1.00	1.05				-2.47	-3.40

Table 8. Cointegrating Vectors and Corresponding Adjustment Matrices

Notes: Normalization was carried out by setting the coefficient on investment equal to -1.00. The cointegrating vectors and the adjustment matrices presented here correspond to the cointegration relationships established in Tables 3-7 and are presented in the same order.

Similarly, in trivariate regressions, the sum of the coefficients on *Y* and *S* is close to 1. The speed of adjustment figures reported in the right hand side columns of Table 8, seem rather high. This holds particularly true for the last decade. This suggests that in the US economy, the time series of investment and saving adjust rapidly to their long-run equilibrium levels.

In sum, using the post-war US quarterly and annual data, I find that the time series of investment and saving are cointegrated, which indicates that the U.S. economy is solvent in the sense that it does not violate its dynamic budget constraint. To conclude, therefore, that it is unlikely that *I-S* correlations would provide accurate information on the true degree of international capital mobility.¹³

6. CONCLUSION

Feldstein and Horioka's (1980) finding that saving and investment tend to be correlated in the long run has received significant attention in the literature. This is because Feldstein and Horioka express the view that the long-run *I-S* comovement is an indicator of international capital immobility. If this were true, then the findings reported in this chapter would suggest that capital was not mobile during the 1947–87 period.

As Baxter and Crucini (1993) note, however, most economists disagree with this interpretation. It is difficult to defend this argument for numerous reasons.

First, the restrictions imposed on international capital mobility have been declining over time in the world economy. This is particularly true since early 70s, when many developed, and to a lesser degree developing, countries abolished most capital restrictions.

Second, the increased deregulation and integration of the world financial markets is not compatible with the idea of declining capital mobility. For example, the extreme volatility of exchange rates since the abandonment of the Bretton Woods' system provides persuasive evidence of capital mobility—a large pool of liquid assets are switched in response to anticipation of exchange rate movements.

Third, studies that measure capital mobility directly using various PPP and interest parity conditions, conclude that capital is very mobile and that capital mobility has been increasing over time. For example, Hutchison and Singh (1993) examine real interest rate differential between the U.S. and Japan and find that capital mobility is very high. Popper (1990) uses interest and currency arbitrage conditions along with financial asset returns and finds that capital is as mobile in the long- as in the short-run.

This chapter claims that there is nothing mysterious in the *I-S* comovement. Since the neoclassical growth theory predicts that in the steady state investment and saving should be proportional to output and therefore would grow at the same rate, it would be surprising if we did not find a high long-run *I-S* correlation. The modern optimizationbased dynamic model of open economy also predicts that investment and saving would be correlated in the long run regardless of the extent of capital mobility, unless the economy violates its dynamic budget constraint. Therefore, a test of *I-S* cointegration is merely a test of country's economic solvency. To conclude, therefore, the observed long-run *I-S* correlation cannot be useful for measuring the extent of international capital mobility.

As additional evidence, it should be noted that if Feldstein and Horioka line of argument were valid, then the huge capital inflow to the U.S. during the first term of the Reagan administration should have diminished the long-run *I-S* correlation in the early 80s. The findings reported here, however, do not support this view.

ACKNOWLEDGEMENTS

I am grateful to the editor, Chris Tsoukis, for his insightful comments, suggestions, and great help. I also thank Marianne Baxter and Maurice Obstfeld, the discussants at the NBER Conference on Macroeconomic Effects of Fiscal Policy, for useful comments, and Tamim Bayoumi, Yunhui Chen, Betty Daniel, Hashem Dezhbakhsh, Clive Granger, Fuku Kimura, Kajal Lahiri, the late G.S. Maddala, Adolfo Sachsida, and the seminar participants at Emory University and SUNY/Albany for comments and suggestions. I thank John Sutton and the Royal Economic Society for a Research Grant Award. All errors are mine.

NOTES

- See, for example, Sinn (1992), Ghosh (1995), Coakley, Kulasi, and Smith (1996), Sachsida and Caetano (2000) and the references cited therein. More recent studies include Tsoukis and Alyousha (2001), Alyousha and Tsoukis (in this volume), and Fountas and Tsoukis (2000), who study a sample of seven industrialized economies.
- See, for example, Bayoumi (1990), Sachs (1981), Obstfeld (1986), Frankel (1991), Levy (1995), Frankel and MacArthur (1988), Popper (1990), and Baxter and Crucini (1993).
- 3. I shall mention that the focus of this chapter is the long-run capital mobility. Short-run capital mobility is less controversial. See, for example, Feldstein (1983) and Levy (2000, 2001).
- 4. Virtually all other macro models, with or without open capital markets, make similar predictions on the long-run investment-saving comovement.
- 5. For example, Barro, Mankiw, and Sala-I-Martin (1995) construct an open economy version of the neoclassical growth model with this conclusion.
- 6. A similar problem arises in the estimation of cointegrating regressions using Engle-Granger two-step method, where the residuals' ADF unit root test statistic distribution depends on the true value of the intercept term. As MacKinnon (1991) notes, all tables assume that $\alpha_1 = 0$, and, therefore, may be quite misleading if this is not the case.
- 7. The reason for the common use of investment and saving rates is to avoid the difficulties the presence of integrated variables create in traditional regression analysis. It turns out, however, that modeling the time series of investment and saving as rates may not be sufficient to make them stationary. See footnote 10 below.

- 8. Miller (1988) considers only investment and saving rates, Otto and Wirjanto (1989) only consider levels, and Gulley (1992) considers both levels and rates.
- To conserve degrees of freedom, I do not divide the annual data into sub-periods because the cointegration test I use employs a maximum likelihood procedure based on error correction representation of the VAR formed by the variables considered.
- It may seem puzzling that investment and saving are *I*(1) in levels as well as rates.
 See Levy (2000, p. 115, footnote 13) for a possible explanation.
- 11. Because of the possibility that investment and saving rates may contain no deterministic trend, the data were also tested for cointegration with the restriction $\mu = 0$, where μ is the vector of constants in the VAR. The result is identical. That is, the time series of investment and saving were found to be cointegrated with one cointegration vector.
- 12. Sinn (1992) also finds that the coefficient is higher for lower frequency data.
- 13. I have also tested for *I-S* cointegration in rates under the assumption that the series don't contain a deterministic trend. The results are the same. It should also be noted that the investment-saving relationships studied here were also estimated recursively and the results indicate significant parameter constancy.

REFERENCES

- Alyousha, A. and C. Tsoukis. "A Re-Examination of Saving-Investment Relationships: Cointegration, Causality, and International Capital Mobility." In this volume.
- Barro, R., N. G. Mankiw, and X. Sala-i-Martin. Capital mobility in neoclassical models of growth. *American Economic Review* 1995; 85: 103–15.
- Baxter, M. and M. Crucini. Explaining saving-investment correlations. *American Economic Review* 1993; 83: 416–36.
- Bayoumi, T. Saving-investment correlations: immobile capital, government policy, or endogenous behavior? *IMF Staff Papers* 1990; 37: 360–87.
- Coakley, J., F. Kulasi, and R. Smith. Current account solvency and the savinginvestment puzzle. *The Economic Journal* 1996; 106: 620–627.
- Engle, R. and C.W.J. Granger. Cointegration and error-correction: representation, estimation and testing. *Econometrica* 1987; 55: 251–76.
- Feldstein, M. Domestic saving and international capital movement in the long run and the short run. *European Economic Review* 1983; 21: 129–51.
- Feldstein, M. and C. Horioka. Domestic saving and international capital flows. *The Economic Journal* 1980; 90: 314–29.
- Fountas, S., and C. Tsoukis. Twin deficits, real interest rates, and international capital mobility. National University of Ireland (Galway), Working Paper No. 49, 2000.
- Frankel, J.A. "Quantifying International Capital Mobility in the 1980s." In National Saving and Economic Performance, B. D. Bernheim and J.B. Shoven, eds. Chicago, IL: University of Chicago Press, 1991.

- Frankel, J.A. and MacArthur, A.T. Political vs. currency premia in international real interest rate differentials. *European Economic Review* 1988; 32: 1083–121.
- Ghosh, A.R. International capital mobility amongst the major industrialized countries: too little or too much? *The Economic Journal* 1995; 105: 107–28.
- Gulley, O. Are saving and investment cointegrated? Another look at the data. *Economics Letters* 1992; 39: 55–8.
- Johansen, S. Statistical analysis of cointegration vectors. *Journal of Economic Dynamics and Control* 1988; 12: 231–54.
- Levy, D. Investment-saving comovement, capital mobility, and fiscal policy. Working Paper No. 90-91-04, University of California, Irvine.
- Levy, D. Investment-saving comovement under endogenous fiscal policy. *Open Economies Review* 1995; 6: 237–54.
- Levy, D. Investment-saving comovement and capital mobility: evidence from centurylong U.S. time series. *Review of Economic Dynamics* 2000; 3: 100–36.
- Levy, D. Are investment and saving cointegrated? A fresh look in frequency domain. Bar-Ilan University and Emory University, Unpublished Working Paper, 2001.
- MacKinnon, J. "Critical values for Cointegration Tests." In Long-Run Economic Relationships, R. Engle and C. Granger, eds. New York: Oxford University Press, 1991.
- Miller, S.M. Are saving and investment cointegrated? *Economics Letters* 1988; 27: 31–34.
- Obstfeld, M. Capital mobility in the world economy. *Carnegie-Rochester Conference* Series on Public Policy 1986, 24: 55–104.

- Obstfeld, M. Comment on D. Levy's "Investment-saving comovement, capital mobility, and fiscal policy," presented at the NBER Conference on Macroeconomic Effects of Fiscal Policy, Cambridge, MA, 1991.
- Osterwald-Lenum, M. A note with quantiles and asymptotic distribution of the maximum likelihood cointegration rank test statistics. *Oxford Bulletin of Economics and Statistics* 1992; 54: 461–71.
- Otto, G. and T. Wirjanto. National saving and domestic investment in the long run: some time series evidence for the U.S. and Canada, Working Paper 1989.
- Popper, H. International capital mobility: direct evidence from long-term currency swaps, International Finance WP No. 386, Board of Governors, Federal Reserve System 1990.
- Sachs, J.D. The current account and macroeconomic adjustment. *Brookings Papers on Economic Activity* 1981, 1: 201–68.
- Sachsida A. and M.A.R. Caetano. The Feldstein-Horioka puzzle revisited. *Economics Letters* 2000; 68: 85–88.
- Sinn, S. Saving-investment correlations and capital mobility: on the evidence from annual data. *The Economic Journal* 1992; 102: 1161–70.
- Tsoukis, C. and A. Alyousha. How mobile is capital internationally: the Feldstein-Horioka puzzle and saving-investment causality. *Journal of Economic Integration* 2001; 16: 262–77.



Figure 1. Investment, Saving, and Output in Levels, Annual Data, 1947-87



Figure 2. Investment and Saving Rates, Annual Data, 1947-87



Figure 3. Investment, Saving, and Output in Levels, Quarterly Data, 1947:1-87:3



Figure 4. Investment and Saving Rates, Quarterly Data, 1947:1-87:3

Bar-Ilan University Department of Economics WORKING PAPERS

1-01	The Optimal Size for a Minority Hillel Rapoport and Avi Weiss, January 2001.
2-01	An Application of a Switching Regimes Regression to the Study of Urban Structure Gershon Alperovich and Joseph Deutsch, January 2001.
3-01	The Kuznets Curve and the Impact of Various Income Sources on the Link Between Inequality and Development Joseph Deutsch and Jacques Silber, February 2001.
4-01	International Asset Allocation: A New Perspective Abraham Lioui and Patrice Poncet, February 2001.
5-01	מודל המועדון והקהילה החרדית יעקב רוזנברג, פברואר 2001.
6-01	Multi-Generation Model of Immigrant Earnings: Theory and Application Gil S. Epstein and Tikva Lecker, February 2001.
7-01	Shattered Rails, Ruined Credit: Financial Fragility and Railroad Operations in the Great Depression Daniel A.Schiffman, February 2001.
8-01	Cooperation and Competition in a Duopoly R&D Market Damiano Bruno Silipo and Avi Weiss, March 2001.
9-01	A Theory of Immigration Amnesties Gil S. Epstein and Avi Weiss, April 2001.
10-01	Dynamic Asset Pricing With Non-Redundant Forwards Abraham Lioui and Patrice Poncet, May 2001.
	Electronic versions of the papers are available at http://www.biu.ac.il/soc/ec/working_papers.html

- 11-01 Macroeconomic and Labor Market Impact of Russian Immigration in Israel
 Sarit Cohen and Chang-Tai Hsieh, May 2001.
- 12-01 Network Topology and the Efficiency of Equilibrium Igal Milchtaich, June 2001.
- 13-01 General Equilibrium Pricing of Trading Strategy Risk Abraham Lioui and Patrice Poncet, July 2001.
- 14-01 **Social Conformity and Child Labor** Shirit Katav-Herz, July 2001.
- 15-01 **Determinants of Railroad Capital Structure, 1830–1885** Daniel A. Schiffman, July 2001.
- 16-01 Political-Legal Institutions and the Railroad Financing Mix, 1885–1929Daniel A. Schiffman, September 2001.
- 17-01 Macroeconomic Instability, Migration, and the Option Value of Education

Eliakim Katz and Hillel Rapoport, October 2001.

- 18-01 Property Rights, Theft, and Efficiency: The Biblical Waiver of Fines in the Case of Confessed Theft Eliakim Katz and Jacob Rosenberg, November 2001.
- 19-01 **Ethnic Discrimination and the Migration of Skilled Labor** Frédéric Docquier and Hillel Rapoport, December 2001.
- 1-02 Can Vocational Education Improve the Wages of Minorities and Disadvantaged Groups? The Case of Israel
 Shoshana Neuman and Adrian Ziderman, February 2002.
- 2-02 What Can the Price Gap between Branded and Private Label Products Tell Us about Markups?
 Robert Barsky, Mark Bergen, Shantanu Dutta, and Daniel Levy, March 2002.
- 3-02 Holiday Price Rigidity and Cost of Price Adjustment Daniel Levy, Georg Müller, Shantanu Dutta, and Mark Bergen, March 2002.
- 4-02 **Computation of Completely Mixed Equilibrium Payoffs** Igal Milchtaich, March 2002.

- 5-02 Coordination and Critical Mass in a Network Market An Experimental Evaluation
 Amir Etziony and Avi Weiss, March 2002.
- 6-02 **Inviting Competition to Achieve Critical Mass** Amir Etziony and Avi Weiss, April 2002.
- 7-02 Credibility, Pre-Production and Inviting Competition in a Network Market Amir Etziony and Avi Weiss, April 2002.
- 8-02 **Brain Drain and LDCs' Growth: Winners and Losers** Michel Beine, Fréderic Docquier, and Hillel Rapoport, April 2002.
- 9-02 Heterogeneity in Price Rigidity: Evidence from a Case Study Using Micro-Level Data

Daniel Levy, Shantanu Dutta, and Mark Bergen, April 2002.

- 10-02 **Price Flexibility in Channels of Distribution: Evidence from Scanner Data** Shantanu Dutta, Mark Bergen, and Daniel Levy, April 2002.
- 11-02 Acquired Cooperation in Finite-Horizon Dynamic Games Igal Milchtaich and Avi Weiss, April 2002.
- 12-02 **Cointegration in Frequency Domain** Daniel Levy, May 2002.
- 13-02 Which Voting Rules Elicit Informative Voting? Ruth Ben-Yashar and Igal Milchtaich, May 2002.
- 14-02 Fertility, Non-Altruism and Economic Growth: Industrialization in the Nineteenth Century Elise S. Brezis, October 2002.
- 15-02 Changes in the Recruitment and Education of the Power Elites in Twentieth Century Western Democracies Elise S. Brezis and François Crouzet, November 2002.
- 16-02 **On the Typical Spectral Shape of an Economic Variable** Daniel Levy and Hashem Dezhbakhsh, December 2002.
- 17-02 International Evidence on Output Fluctuation and Shock Persistence Daniel Levy and Hashem Dezhbakhsh, December 2002.

1-03 **Topological Conditions for Uniqueness of Equilibrium in Networks** Igal Milchtaich, March 2003.

2-03 Is the Feldstein-Horioka Puzzle Really a Puzzle? Daniel Levy, June 2003.