TESTING SAVING AND INVESTMENT RATES TO UNDERSTAND CAPITAL MOBILITY AND CURRENT ACCOUNT SOLVENCY

by

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Feldstein and Horioka (1980) motivated the international finance literature by claiming a least squares regression of domestic investment rates on domestic savings rates is an informative measure of capital mobility. Their method stirred up controversy when they interpreted a high correlation between savings and investment rates as evidence of capital immobility, creating the famous Feldstein-Horioka puzzle. Current research starts with the Feldstein-Horioka result and shifts focus toward measuring short and long-run adjustments to external imbalances. The literature has implemented dynamic time-series and panel estimators to test the relationship. Following recent literature, each chapter in this

dissertation jointly focuses on the adjustment process of current account imbalances and the conditions required for capital mobility.

The intent of this study is to show through the use of new estimation techniques previous results have been largely misguided. The starting point for this analysis is a thorough review of three key equations used in saving-investment regressions. The three models in question are an ordinary least squares model, error correction model, and an autoregressive distributive lag estimator. Each model is tested for stability, and it is found that a number of countries have an unstable relationship. One argument for the instability results is the presence of structural breaks. Previous literature has found that both variables follow non-stationary processes, but when using more powerful unit root tests and controlling for level shifts, both variables appear stationary. If each variable is stationary then previous methods assuming non-stationarity will produce incorrect inferences. Each series is optimally estimated for structural breaks, and through a mean differencing process the savings-investment coefficient is significantly reduced. Additionally, removing the exogenous breaks and using the lower frequency components allows for modeling the short-run current account adjustment process. Finally, the results are extended to measure the relationship in a panel framework using dynamic panel estimators and threshold effects. After controlling for structural breaks the coefficient decreases and exhibits a downward trend. The remaining correlation can be explained through trade openness and country size measures.

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For my mom, wife, and son.

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CHAPTER I

INTRODUCTION

The Beginning

Saving and investment rates have received considerable attention following Feldstein and Horioka (1980). Feldstein and Horioka use an ordinary least squares regression to test the relationship between saving and investment rates for a sample of 16 OECD countries from 1960-1974.[1] The authors interpret a finding of a unity coefficient on saving rates as evidence of perfect capital immobility. This result generated a large debate over the usefulness of saving-investment regressions to measure the degree of capital mobility. Today is it commonly accepted a high association between saving and investment occurs even under conditions allowing for perfect capital mobility. Countries are constrained by an intertemporal long-run budget constraint which will force savings and investment rates will converge over time. A number of authors have pointed out the use of dynamic time series models have the capability to model a short-run relationship to measure the degree of capital mobility while jointly controlling for the long-run budget constraint through testing for current account stationarity.

[1]Saving and investment rates are expressed as a percentage of gross domestic product.

The Feldstein and Horioka result has been cited in more than 500 papers. The literature has progressed through cross-sectional, time-series, and dynamic panel econometric methods to explain the relationship. Despite the large body of work there are a number of areas that warrant further analysis. Three areas that require further inspection are the use of constant parameter linear time series models, integration properties for both variables, and the effects of structural breaks on the saving-investment relationship. I show previous estimations of linear time series models are biased from the failure to control for varying parameters. Next I find the failure to adequately test the integration properties of saving and investment rates has lead to the widespread failure to reject non-stationarity. In particular, test results are significantly distorted by the presence of structural breaks. Controlling for structural breaks within the saving-investment regression reduces the savings coefficient. In addition to showing a significant reduction in the savings coefficient after controlling for structural breaks, these results are also consistent with a lower savings coefficient in cross-section regressions through the estimation of threshold effects and dynamic panel models.

Within this dissertation I argue the saving-investment correlation is a result of a failure to appropriately model the relationship. Figures 1.1 and 1.2 show the time paths for both variables. Looking at these figures generate a number of important questions that have yet to be answered:

- What is the current relationship between saving and investment rates?

- Has the relationship changed over time? Does this correspond with higher measures of capital mobility?
- Is there a difference between the short-run and long-run relationship?
- Are the results affected by presence of structural breaks?
- How should structural breaks be controlled in each series?
- Are there any other variables that could cause the correlation?
- Are the results consistent using dynamic panel techniques?

These questions will be answered throughout the following chapters. Not only will the statistical properties be tested, but added emphasis will be placed on the importance of understanding saving and investment dynamics in relation to capital mobility and current account dynamics.

The process for testing saving and investment regressions is the following: Chapter two will provide updated results for three key models used to measure the saving-investment relationship. The models consist of an ordinary least squares regression following the original model proposed by Feldstein and Horioka, an error correction model proposed by Jansen (1996) and Coakley et al., (1996), and an autoregressive distributive lag model first used by De Vita and Abbott (2002). The goal of chapter two is to provide the reader with a basic overview and understanding of saving-investment regressions. This chapter extends the literature by estimating the autoregressive distributive model for the entire OECD sample and testing the models for parameter constancy using newer, more efficient parameter stability tests. Each regression assumes parameter constancy, but given the large number of current account reversals, changes in capital controls, and global business cycles over the last half century, it is unreasonable to assume the savings coefficient has remained constant. Failing to control for shifts in either variable will bias the results. Elliott and Müller (2006) provide general stability tests for linear regressions. Implementing these stability tests shows simple constant parameter models fail to account for either time varying parameters and/or structural breaks. Saving-investment regressions are found to be unstable.

Given the instability of the saving-investment regressions, chapter three proceeds with basic pretests for saving and investment rates. Unit root tests are conducted following the traditional augmented Dickey-Fuller, Phillips-Perron, and Kwiatkowski, Phillips, Schmidt, Shin (1992) tests. It is well documented these tests have lower power when a stationary series has an AR(1) coefficient near unity. A more powerful unit root test proposed by Elliott, Rothemberg, and Stock (1996) is implemented. One additional concern is the low power unit root tests possess in the presence of structural breaks. The inclusion of structural breaks will bias unit root tests in favor of the non-stationary hypothesis. To control for structural shifts the single mean shift models of Perron and Vogelsang (1992) and the double mean shift extensions following Clemente, Montañés, and Reyes (1998) are estimated. The results provide strong evidence against the unit root hypothesis.

Previous literature has reported a close association between savings and investment rates, and I argue the high correlation is from the presence of structural breaks. One common argument for the high correlation is the endogeneity of both variables. For instance a global shock will jointly affect savings and investment rates. The movement in both variables makes them highly correlated, independent of the degree of capital mobility. The previous chapter pointed out unit root tests for savings and investment rates are biased because of level shifts. The objective of chapter four is to optimally estimate breaks dates in both variables and apply the results to the saving-investment regressions.

Controlling for structural breaks within the unit root literature maintains an objective of minimizing the t-statistic associated with the AR(1) coefficient. Unfortunately this does not necessarily coincide with the optimal break date. Furthermore unit root tests have only been well developed for the one and two break cases. In chapter four I present the results for a likelihood ratio test allowing for a multiple change model outlined in Bai (1999). This procedure uses a simultaneous estimation procedure to test for the existence of l breaks against the alternative of $l+1$ breaks. Prior papers rely on testing for $l+1$ within one of the subsamples separated by the l breaks. This procedure will determine the optimal break date. This is vital in attempting to understand which variables are responsible for causing the high correlation. The structural change model tests for a shift in the mean of saving and investment rates independently and in the saving-investment regression allowing for complete parameter breaks. The latter approach provides insight on the overall long-run degree of capital mobility and the former method measures the degree of capital mobility within each break sample. After controlling for structural breaks in saving and investment rates, the savings coefficient is significantly lower for the majority of countries.

In addition to testing for optimal breaks it is equally important to understand the variables that have caused these breaks to occur. Savings and investment rates are likely to shift following changes in the global business cycle and domestic policies such as changes in exchange rate regimes, taxes on international capital flows, trade agreements, and domestic taxes. Changes in economic growth rates and trade openness are shown to be likely variables that cause saving and investment rates to shift.

Controlling for structural breaks explains a large portion of the saving-investment relationship, but the relationship remains significant for a number of countries. It is important to be able to explain the remaining correlation and show the results correspond with a lower savings coefficient in a cross sectional analysis. Frankel (1985) first pointed out the use of saving-investment regressions are only consistent for small open economies. In order to test how the relationship differs across country size and trade openness the variables are tested using dynamic panel estimators following Pesaran and Shin (1995) and Pesaran, Shin, and Smith (1997, 1999) and threshold effects following Hansen (2000). There have been a number of methods used within the literature to test the importance of trade openness and country size on the saving-investment relationship; the most common approach is to split the data set into arbitrarily defined sample groupings and test the sensitivity of the savings coefficient. Ho (2003) incorporates the use of threshold effects to test the effect of country size on the savings coefficient. The threshold approach controls for common shocks and individual country effects. I use the mean differenced data from chapter four to test the effects of structural change on the cross section regressions. The results confirm previous research, the savings coefficient is lower in the cross section and for small open countries.

In the end I show previous attempts to model the savings and investment relationship have produced biased results stemming from the assumption of constant parameters. I show the savings coefficient is significantly lower after optimally estimating country and variable specific structural breaks. Furthermore, these results help to explain a lower savings coefficient in dynamic panel regressions. Incorporating threshold effects from trade openness and country size explains the remaining correlation. Throughout the paper I place added emphasis on jointly interpreting capital mobility and current account adjustments within the saving-investment context. When controlling for structural breaks most countries exhibit a much higher degree of capital mobility. These results are confirmed using dynamic panel and threshold effects.

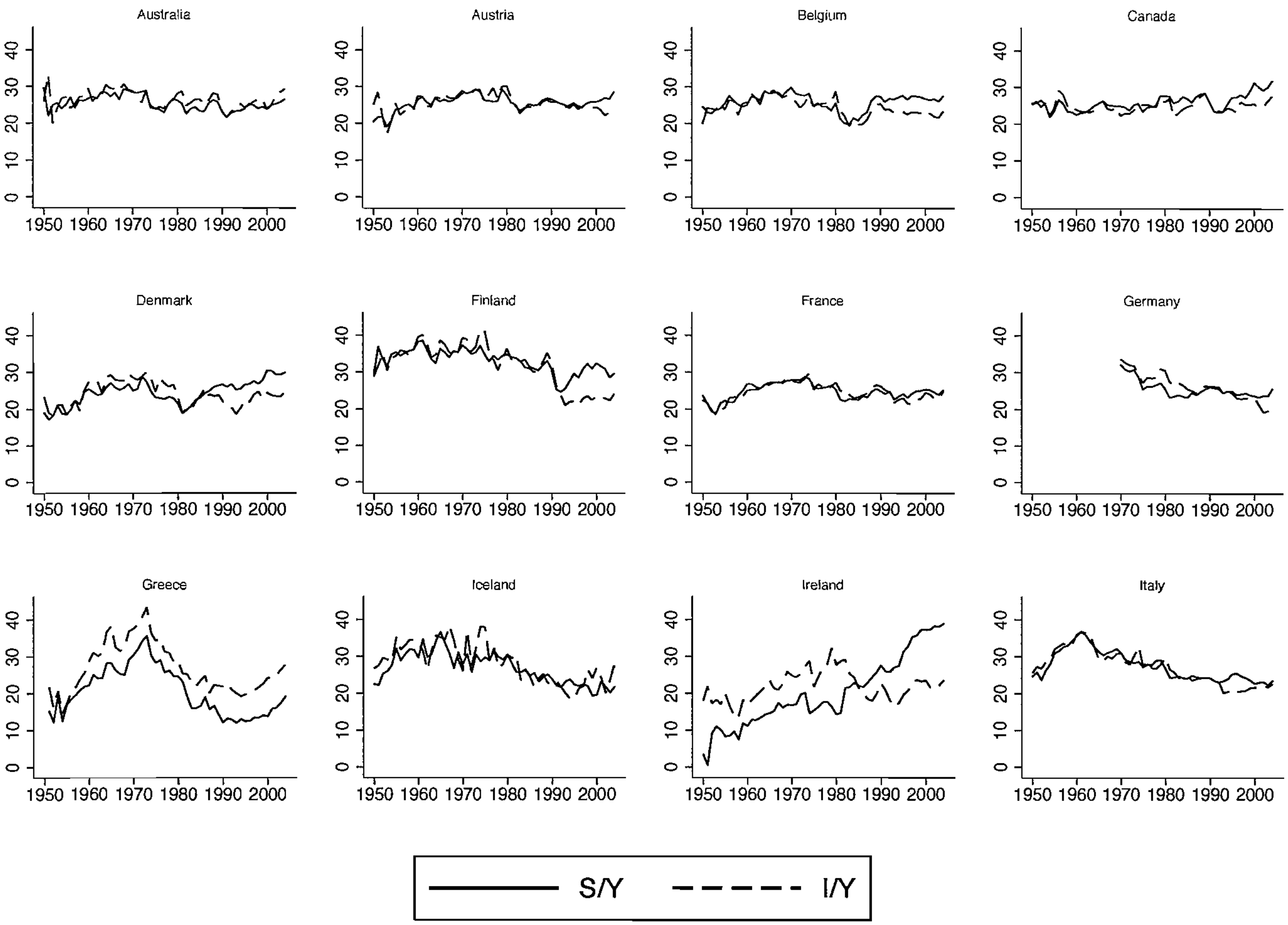

Figure 1.1. Saving and Investment Rates 1950-2004, Australia - Italy

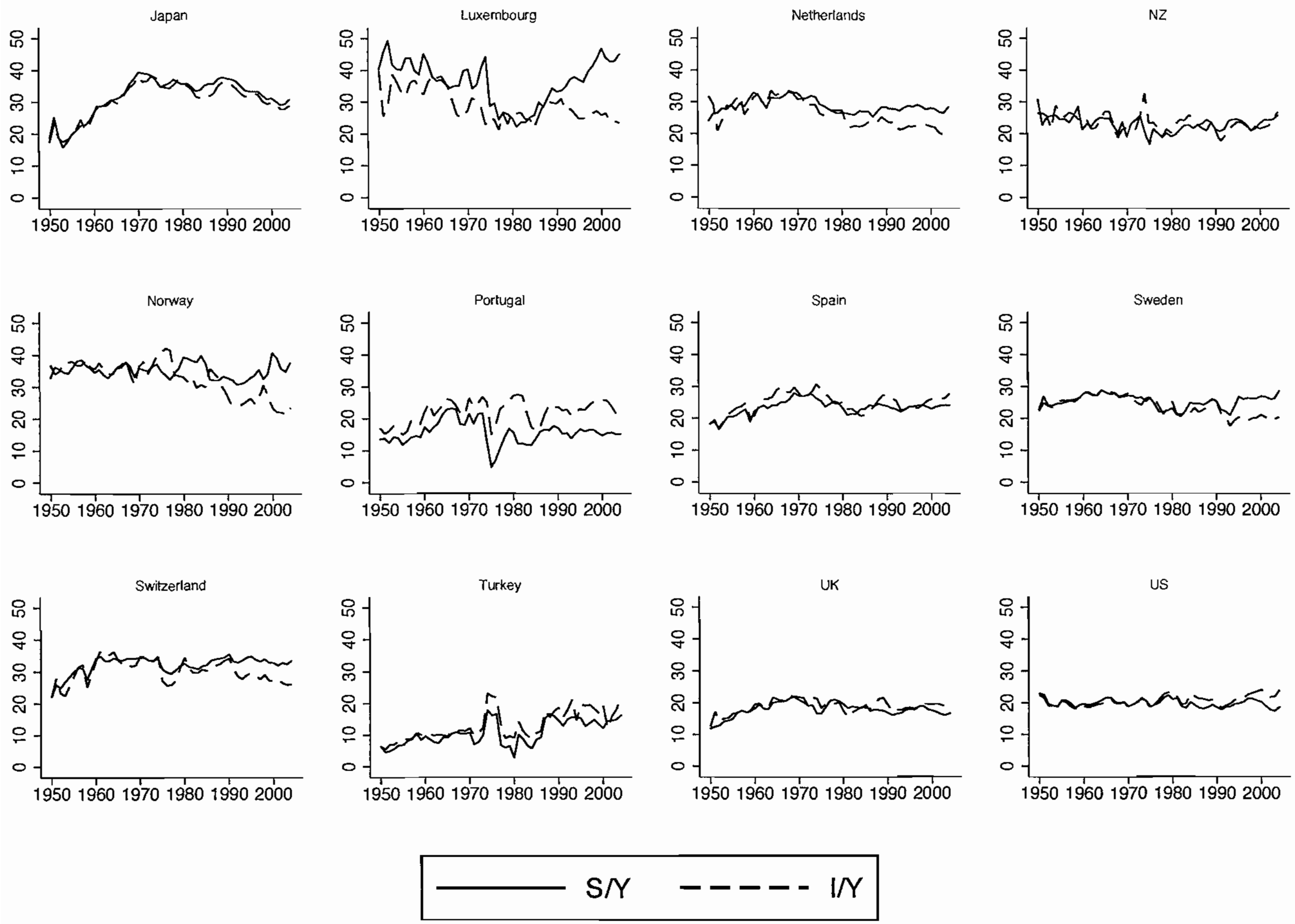

Figure 1.2. Saving and Investment Rates 1950-2004, Japan - U.S.

CHAPTER II

OVERVIEW OF THE FELDSTEIN-HORIOKA PUZZLE

Introduction

Modeling the saving-investment relationship has continued to stir the creative juices of economists for near thirty years. Similar to research attempting to explain other puzzles within the international finance literature, notably the purchasing power parity and forward premium puzzles, the saving-investment relationship is often used as a testing grounds for new time series and dynamic panel estimators. As long as new estimation techniques, data, and computing capabilities expand, new tests of the saving-investment relationship will continue on indefinitely. Nevertheless expanding the puzzle to newer, more powerful estimators will only provide a marginal improvement into the intuition for the long-run relationship. While testing the saving-investment relationship by country, researchers have relied on three key equations: an ordinary least squares regression, error correction representations, and autoregressive distributive lag models. The goal of this chapter is to review the literature associated with each model and to extend the results to cover most OECD countries from 1950-2004. This will provide the basic intuition for the recent trends in capital mobility over the last half century. In addition to thoroughly covering the key equations the last section will review the assumption of parameter constancy used throughout the chapter. Given the dynamic nature of capital mobility and current account balances it seems reasonable to test the constant parameter assumptions. Tests following Elliott and Müller (2006) show the previously estimated regression parameters are unstable.

The rest of the chapter will provide a brief overview of the time series models used in the context of the saving-investment relationship. In short this chapter can be seen as a critical assessment of traditional saving-investment regressions. The main findings are traditional saving-investment tests are unstable and inferences in regards to capital mobility and current account dynamics are likely to be misleading. Section 1 reviews the time series literature associated with saving-investment regressions. Section 2 will provide the intuition and results for the baseline Feldstein-Horioka model. The first major extension of the baseline model was provided by Jansen (1996) in which he argues an error correction model is the correct representation for the saving-investment relationship. Section 3 will review the error correction model and provide results. The error correction representation has become the work horse model in the literature as it provides a test for cointegration and jointly captures short-run dynamics. The error correction model does have a few shortcomings. For instance, most authors assume saving and investment rates are non-stationary but De Vita and Abbott (2002) point out there is substantial uncertainty over the time series properties.[1] The autoregressive distributive lag model can be seen as a generalized version of the error correction model, but does not require a definite decision over the integration properties (Pesaran and Shin, 1999).[2] Section 4 tests the relationship using an autoregressive distributive model and finds more countries exhibit capital mobility than previous estimates. One extension of this paper is the implementation of newer stability tests which test for parameter constancy. Both variables exhibit large amounts of volatility and it is unreasonable to assume parameter constancy over a 55 year period. Section 5 applies the Elliott and Müller (2006) test for parameter stability against a range of alternative hypotheses. Finally, Section 6 discusses the implications of the instability results, future courses of research, and concludes.

Literature Review

Attempts to understand the dynamic nature of saving and investment rates have been ongoing for years. Both variables play an instrumental part in determining long-run growth rates, current account solvency, and capital mobility. Unfortunately the relationship between savings and investment rates is not easily identifiable. Solow (1956) showed in the short-run a country's steady state level of output can be increased through policies targeting higher saving rates that promote

[1]The stationary properties for both variables will be explored in the following chapter.

[2]Within the saving-investment literature, the error correction model has been tested under the maintained assumption both variables are nonstationary, but this is not an assumption of the model, see Banerjee et al., (1992).

capital accumulation. An increase in the capital stock will increase the amount of capital per unit of effective labor. This result created a large policy debate over the importance of targeting savings or investment rates. Should policymakers create more incentives to save which in turn increases the amount of loanable funds lowering the interest rate resulting in higher levels of investment, or are higher saving rates an aftermath of higher growth rates? In addition to their relationship with economic growth both variables can provide information for capital mobility and current account dynamics.

The Solow model also provides a relatively simply explanation for saving and investment behavior across countries. In a global economy where countries are represented by the Solow model, without impediments to capital flows marginal productivity of capital should be equal across countries. If saving rates increase in one country and the excess funds are reinvested within the home country the marginal productivity of capital will decrease creating incentives to invest abroad. Indirectly, Feldstein and Horioka (1980) were interested in testing if the global economy followed the basic Solow model. Feldstein and Horioka attempted to measure the degree of capital mobility in order to determine the appropriate rates of taxation on foreign capital. Feldstein and Horioka estimated a two variable OLS model between investment and saving rates, each variables is expressed relative to gross domestic product. Feldstein and Horioka used a sample of OECD countries from 1960-1974. They found β, the savings coefficient, insignificant from unity.[3] They interpret the high correlation as evidence of imperfect capital mobility. Given the data structural and time span the result should not be that surprising. Feldstein and Horioka test the relationship using annual data average over 5, 10, and 15 years periods to control for business cycles. Using data averaging has been shown to bias the savings coefficient toward unity (Sinn, 1992). In addition to data averaging, the time span from 1960-1974 is period associated with low capital mobility. Despite these factors the puzzle has remained in a number of samples commonly associated with high capital mobility.

Given the standard assumption of perfect capital mobility in open-economy models, it was a shock to many researchers when Feldstein and Horioka found a high correlation between domestic saving and investment rates. Given the importance capital mobility has on policymaking, a number of attempts have been made to reconcile the high correlation between saving and investment rates with increasing capital mobility. Obstfeld and Rogoff (2000) have labeled the high correlation one of the six puzzles within the international finance literature. Recent literature finds the correlation has declined over time, but remains significant. The relationship is weaker for developing countries and industrialized countries in the early 20th century. With evidence of a lower savings coefficient in periods associated

[3] β is often referred to as the saving coefficient, saving retention coefficient, or the correlation coefficient.

with capital mobility there is not a strong consensus over possible explanations for the high correlation today.

There are essentially two threads of research relating to saving-investment regressions. The first thread attempts to use the saving-investment methodology to form a better understanding of capital mobility through empirically testing the relationship. The objective is to test the relationship controlling for variables relevant to capital mobility including country size, trade openness, common exogenous shocks, transactions costs, and non-traded goods. The second thread is more pessimistic over the use of saving-investment regressions to measure capital mobility. The high correlation is a statistical artifact of country specific long-run budget constraints and current account solvency conditions. This group has focused their research efforts on jointly modeling the short-run and long-run relationship to infer capital mobility.

Given the large amount of research into the saving-investment puzzle, the objective of this section is to briefly review the literature focusing on the time series techniques used to test the relationship. Although Feldstein and Horioka initially focused on cross-sectional data, Obstfeld (1986) states there are four reasons for using time-series regressions instead of using cross-sectional regressions.

- Time series regressions provide a set of empirical regularities with which theoretical open-economy models must be consistent. These empirical regularities also suggest hypotheses that may inspire more powerful tests in the future.

- Estimation of the coefficients and their asymptotic distributions permits a heuristic assessment of the significance of their difference from the value of 1 that would obtain under complete capital immobility.

- The results can provide guidance on the appropriateness of pooling time-series observations on different countries, as in Feldstein (1983). In fact, the data give a strong indication that such pooling is not appropriate.

- Even though short-run saving and investment changes need not be uncorrelated under perfect capital mobility, measures of their correlation are likely to be unaffected by some of the forces that may limit protracted current-account imbalances over longer periods.

Obstfeld's suggestion to use time series data dramatically increased the scope of the saving-investment puzzle. Obstfeld found significantly lower savings coefficient and a sharp decrease after the ending of the fixed exchange rate period in 1973.

Miller (1988) was the first to apply time series tests to the saving-investment relationship. Miller tests saving-investment regressions for cointegration using Engle-Granger's (1987) two-step approach. Miller hypothesized that saving-investment regressions were spurious. Because both variables are non-stationary the residuals must be stationary or the regression will be classified as spurious. Miller focuses his efforts toward the United States and finds saving-investment rates are non-stationary and cointegrate during the Bretton Woods period but rejects cointegration after the break down of the fixed exchange rate regime. Gulley (1992) shows Miller's result stems from inappropriate unit root testing procedure. Gulley shows the inclusion of an intercept term reverses Miller's conclusion. Gulley is unable to detect an increase in capital mobility during the movement into floating exchange rates. Leachman (1991) was the first to apply cointegration tests to a complete sample of OECD countries. She finds all countries have non-stationary saving and investment rates but the two variables are not cointegrated. De Hann and Siermann (1994) argue Leachman's test suffers from lower power attributed to a short time span of 25 annual observations. Instead De Hann and Siermann use a long span data set for 10 countries and conclude saving and investment rates are cointegrated for five countries.

Gundlach (1992) argues evidence of a non-stationary current account confirms capital mobility and is superior to testing saving-investment regressions. Gundlach uses data for a sample of OECD countries and reports a lower likelihood of current account stationarity after 1972, implying an increase in capital mobility. Gundlach's approach is very sensitive to length of data; often times countries experience current account imbalances for extended periods but eventually long-run solvency constraints force countries to offset these imbalances. Unit root tests applied to a country's current account balance are likely to be biased toward the non-stationary hypothesis. Coakley and Kulasi (1997) use Maddison's long span data and show the current account is stationary for most countries with the exceptions of Germany and United Kingdom.

Instead of relying on residual based cointegration tests, Argimon and Roldan (1994) use Johansen's maximum likelihood procedure to test for cointegration. The authors test if investment is cointegrated with total saving, public saving, and/or private saving. They find investment is only cointegrated with aggregate saving for a handful of European countries (Spain, France, Italy, Denmark, and Belgium). Jointly public and private saving may appear to be immobile, but independently both variables are unrelated to investment rates. Barkoulas, Filizetkin, and Murphy (1996) test 24 OECD countries using Johansen's trace test statistic and find little evidence supporting cointegration, thus concluding capital is mobile.

Jansen (1996), (1997), and (1998) and Coakley (1996) independently argue the use of an error correction model is a better representation to model saving and investment dynamics. The error correction model measures both the short-run dynamics and the long-run cointegrating relationship. Jansen models the saving-investment relationship using an error correction model following Kremmers, Ericsson, and Dolado (1992). Jansen estimates the following equation:

$$\Delta i_t = \alpha + \beta \Delta s_t + \gamma(s_{t-1} - i_{t-1}) + \varepsilon_t. \quad \text{(II.1)}$$

Jansen assumes both variables are non-stationary; if $\gamma \neq 0$ then saving and investment rates have a long-run relationship. If both variables are I(1) this implies cointegration with $(1, -1)'$ cointegrating vector. This implies saving and investment rates have a long-run relationship with a stationary current account, $(S/Y - I/Y)$, around $-\alpha/\gamma$. This result reflects the binding long-run intertemporal budget constraint of an open economy. Jansen finds for a number of countries saving and investment rates cointegrate, a constant current account, evidence of short-run capital mobility, and a significant structural break between 1973 and 1974. Jansen places added restrictions on the error correction model by assuming saving and investment cointegrate with a $(1, -1)$ vector. Resorting to economic theory, Jansen argues this assumption arises from the long-run budget constraint.

Estimating the long-run relationship provides insight for current account stability, speed of adjustment, and capital mobility. The use of cointegration tests have been widely implemented to test the long-run solvency hypothesis. If saving and investment rates are non-stationary and cointegrated there exists a long-run relationship, i.e. the saving coefficient from the Feldstein and Horioka model will be near unity. It is important to note cointegration does not necessarily imply a binding intertemporal budget constraint. Current account targeting (Summers, 1987) and low capital mobility can also cause a long-run association. Jansen (1997) constructs a Monte Carlo study to test the cross-section relationship when both variables are non-stationary and cointegrated. Jansen shows for a low savings coefficient, in the time series domain, the savings coefficient in a cross-section regression is near zero. The cross-sectional correlation is lower when cointegration is rejected. Cross-section correlation increases when there is a greater probability of cointegration and higher country specific savings coefficients. Jansen concludes the intertemporal budget constraint is sufficiently powerful to explain the high correlation.

Coakley and Kulasi (1997) apply Johansen's maximum likelihood procedure and the error correction model outlined above to a long span data set for 11 countries. They argue the Feldstein-Horioka results is a statistical artifact of the cross-section regressions. Since both variables appear non-stationary, a solvency constraint requires the current account to follow a stationary process. In order to test the solvency constraint the authors incorporate a variety of cointegration tests and find seven countries (Australia, Canada, France, India, Japan, the Netherlands, and United Kingdom) have saving and investment rates that cointegrate. The authors also find both variables are stationary for the United States.

Mamingi (1997) was the first to test the relationship using a sample of developing countries. In addition to an error correction model, Mamingi uses a fully modified OLS estimator to control for endogeneity and serial correlation, which asymptotically eliminates sample bias. Mamingi concludes saving-investment correlations are lower for developing countries which provides evidence of imperfect capital mobility. Hussein (1998) tests the relationship for a sample of OECD countries using a dynamic OLS model. The dynamic OLS equation incorporates lags and leads of saving rates to eliminate the effect of endogeneity and lags of investment to control for serial correlation. Hussein shows the saving coefficient is significantly different from unity for 18 of the 23 OECD countries and finds the coefficient has declined over the last two decades. The dynamic OLS model is more appropriate for long span data; the estimation of lags and leads for both variables requires estimating a large number of coefficients and causing a large loss in degrees of freedom. This could be problematic for the shorter data sets used in the saving-investment literature.

There is some debate over the time series properties for both variables; each variable appears to follow a random walk, is derived from national accounting identities, and expressed as a percentage of gross domestic product, but a number of authors have found both variables non-stationary. Given the uncertainty over the stationary properties of saving and investment rates, De Vita and Abbott (2002) test the long-run relationship using an autoregressive distributive lag bounds (ARDL) approach. Pesaran and Shin (1999) show the ARDL bounds testing method to test for cointegration does not require both series to be I(1) thus allowing saving-investment regressions to be tested in a single equation model without prior knowledge of the level of integration. De Vita and Abbott (2002) find saving and investment rates cointegrated for the United States but the relationship does weaken during the more liberalized floating exchange rate regimes. Corbin (2004) uses long-span data from 1880-2001, but argues the autoregressive distributive lag model is uninformative over capital mobility movements in the long-run. Instead Corbin uses the model to measure the speed of adjustment in the current account to infer short-run capital mobility. Corbin concludes the current account adjustment process has slowed for a sample of countries but there is a high level of capital mobility prior to World War I and following the Bretton Woods period. Kollias, Mylonidis, and Paleologou (2006) apply the autoregressive distributive lag approach to 15 European Union members. Kollias et al. find no relationship between the degree of capital mobility and country size, level of development, and economic and capital market structures.

Capital Mobility

There are two approaches for testing capital mobility. The first approach involves a structural model that requires testing interest rate differentials on capital across countries. This approach requires controlling for a number of variables including: inflation, expected inflation, currency fluctuations, expected appreciation or depreciation, political risk, tax rates, transaction costs, capital controls, investor preferences, and additional uncertainty. The second approach proposed by Feldstein and Horioka consists of testing the relationship between domestic saving and investment rates. Both approaches have benefits and costs. The use of a structural model guides the first estimation process. The structural model is often grounded in economic theory; thus the empirical models are only as good as the underlying theory, choosing appropriate variables is difficult, and there are a number of econometric issues. Feldstein and Horioka's approach is novel, but using saving-investment regressions to measure capital mobility is controversial. A country can run a large current account deficit for a number of years and have saving and investment rates perfectly correlated during this period. Despite the criticism of using saving and investment rates to infer capital mobility in the traditional Feldstein-Horioka model, the relationship can still be informative to measure capital mobility when both variables are appropriately modeled in the time series context.

Feldstein and Horioka (1980) were the first to apply saving-investment regressions to measure capital mobility. They argue a lower (high) savings coefficient is evidence in favor of capital mobility (immobility). As seen above, a number of researchers claim the high correlation is a statistical artifact of a binding intertemporal budget constraint. Next it is common to test saving and investment rates for a cointegrating relationship, if saving and investment rates are not cointegrated capital is mobile. If a long-run relationship is found significant then is capital is immobile. The main criticism of cointegration tests is the inability to jointly model short-run and long-run dynamics.

Jansen (1996) and Coakley (1996) also argue relying on cointegration tests to test for capital mobility is inappropriate. Jansen shows the error correction representation is a more adequate representation. In the error correction framework there are three different outcomes that detect capital mobility. Capital mobility exists if non-cointegration fails to be reject, saving and investment rates are cointegrated but the current account is non-stationary, and saving and investment rates are cointegration, the current account is I(0), but the savings coefficient measuring the short-run correlation is small. In the context of the saving-investment literature the autoregressive distributive lag models are an extension of the error correction model. The conditions for capital mobility are equivalent but the testing procedure is different. This will be explored in more detail in the following chapter.

Baseline Model

Understanding the degree of capital mobility is important as capital mobility is a necessity for efficient allocation of the world's saving. Capital mobility allows countries to diversify asset holdings and minimize risk (Obstfeld 1986). Furthermore, having a measure of capital mobility is critical for optimal financial policies regarding taxes rates on foreign capital and international investment gains. Feldstein and Horioka (1980) were interested in testing the degree of capital mobility to be able to better form tax policy. Their objective was to determine how the government should target saving policies. If a country is closed to capital markets extra saving will be invested domestically. The individual investor will receive the after tax returns and the government will collect additional tax revenue from capital gains. Saving decisions are determined by the pre-tax marginal productivity of capital. Conversely, if capital markets are open additional saving will most likely flow to other countries. In this case the nation will only receive the after tax returns. They go on to argue a large portion of the tax base comes from taxes on capital incomes and in a world with perfect capital mobility a substitution into international assets could cause large, adverse budgetary effects.

In order to test the existence of capital mobility, Feldstein and Horioka estimate a cross-sectional regression of investment rates on saving rates:

$$i_i = \alpha + \beta s_i + \varepsilon_i \tag{II.2}$$

where $i = I/Y$ and $s = S/Y$ are expressed relative to gross domestic product. Feldstein and Horioka use a sample of OECD countries from 1960-1974. They find β insignificant from unity.[4] In order to control for business cycle effects the authors averaged both variables ranging from five to fifteen years. The decision to use period averages generates a large amount of criticism. Coakley et al., (1996) point out countries face external budget constraints and over time the average of saving and investment rates will converge. Nevertheless, the puzzle has remained even with using annual data.

Following Obstfeld (1986), the starting point for the analysis is a simple extension of the original model. The following equation is estimated:

$$i_t = \alpha + \beta s_t + \varepsilon_t. \tag{II.3}$$

The only noticeable change is in the subscripts denoting time periods. Obstfeld shows time series regressions are more applicable to economic theory and Sinn (1992) argues the use of period averages will likely bias the coefficient towards unity.

[4] β is often referred to as the saving coefficient, saving retention coefficient, or the correlation coefficient.

Using period averages will only model the long-run relationship; saving and investment rates are tied together through the intertemporal budget constraint and over time countries must finance deficits with a future surplus. Averaging saving and investment rates will cause a strong correlated which should not be taken as capital immobility.[5] Using period averages ignores the dynamic nature of the saving-investment relationship. Sinn goes on to show the saving coefficient is much lower than unity, but still significant.

Equation II.3 provides some intuition for understanding the saving-investment relationship, but unfortunately offers very little interpretation for the relationship over time. Georgopoulos and Hejazi (2005) estimate the traditional saving-investment regression with a trend term interacted with saving rates. They estimate the following:

$$i_t = \alpha + \beta s_t + \gamma s_t trend + \varepsilon_t. \tag{II.4}$$

The coefficient of interest is defined as $\beta + \delta_1 t$. If $\gamma < 0$ ($\gamma > 0$) then capital mobility is increasing (decreasing) over time.

I add one minor extension to Georgopoulos and Hejazi by including an additional term capturing the interaction between saving rates and $trend^2$. This term will provide evidence of increasing or decreasing capital mobility and the rate of change in capital mobility. In addition to estimating equation II.4 the following

[5]Coakley (1996) refers to this as the current account solvency condition.

equation is estimated:

$$i_t = \alpha + \beta s_t + \delta_1 s_t t + \delta_2 s_t trend^2 + \varepsilon_t. \quad \text{(II.5)}$$

The coefficient of interest is $\beta + \delta_1 t + \delta_2 trend^2$. The interpretations of δ_1 and δ_2 are slightly more difficult. Table 2.1 provides a list of the possible outcomes for different combinations of δ_1 and δ_2. There are a number of interesting outcomes. For example, estimation of equation II.4 could yield a positive δ_1 implying decreasing capital mobility, but under case three it is possible to have capital mobility higher in the future if δ_2 is relatively large (in negative value) and δ_1 is small. Looking ahead at the results this is the case for a number of countries. There are a number of other

Table 2.1. Interpretation of Saving Coefficients with T^2

Case	δ_1	δ_2	Capital Mobility
1	< 0	< 0	Decreasing at an increasing rate
2	< 0	> 0	Decreasing at a decreasing rate
3	> 0	< 0	Increasing at a decreasing rate
4	> 0	> 0	Increasing at an increasing rate

estimation techniques that could be explored. Currently the literature has moved into the use of panel data estimators to explain the correlation between saving and investment. These methods provide little intuition at the country level. In addition to panel estimators a number of additional variables have been included to explain the puzzle. Future chapters will explore the effects of key variables, i.e. trade openness and country size, on the puzzle. First and foremost it is necessary to understand the nature of the puzzle before attempting to explain the patterns.

Annual data from the Penn World Table was used to estimate equations II.3, II.4, and II.5 for 24 OECD countries.[6] The results for all three equations are presented in table 2.2. The results from the Feldstein-Horioka regression suggest Finland, France, Germany, Greece, Iceland, Italy, Japan, Netherlands, Spain, Switzerland, and Turkey all have saving coefficients near unity. Surprisingly only Ireland and Norway have saving coefficients statistically insignificant from zero. Luxembourg has a coefficient near zero, but statistically significant. Ireland, Luxembourg, and Norway are fast growing small, open economies. Finding a savings coefficient near unity is not surprising in a sample of developed countries. Because developed countries are more likely to be producing at or near their steady state these countries will have a similar level of marginal productivity. If the marginal productivity of capital is equal across countries and investors have home bias the savings coefficient will not differ from unity. This is the case for France, Germany, Italy, and Spain. Unfortunately the steady state argument does not explain the high correlation for the remaining countries. The remaining countries, including the United States and United Kingdom, have an intermediate degree of capital mobility.

It is easy to get caught up in the high correlation reported from equation II.3, but one needs to be reminded that a number of relevant variables are excluded. These exclusions will most likely bias the coefficient toward unity. The first step in

[6] Korea, Mexico, Hungary, Poland, Czech Republic, and Slovak Republic were excluded from the analysis. They became members between 1990-2000, are arguably transition/developing economies, and have a number of data issues.

getting a better understanding of the relationship is to include a trend term to measure the relationship over time. The results from equation II.4 are reported in table 2.2. The trend coefficient, γ, is negative for most countries. This corresponds with the common view capital mobility has been increasing. Australia, Greece, Portugal, Turkey, United Kingdom, and United States have experience decreasing capital mobility over time. In many all cases the saving coefficient increases from equation II.3, but does have a decreasing trend.

The inclusion of a trend term explains the direction capital mobility has changed over the last fifty years, but nevertheless places added assumptions on capital mobility. It assumes capital mobility has changed at a linear rate. A more appropriate response would be to include an additional term capture nonlinear changes to capital mobility. This is achieved by interacting saving rates with $trend^2$. The results from equation II.5 are presented in the last three columns of table 2.2. To make the results easier to interpret, figures 2.1 and 2.2 show how the savings coefficient evolves over time for the previous three regression.

As expected most countries have a decreasing savings coefficient and higher levels of capital mobility. Greece and United States are two exceptions. Both countries have been running large current account deficits combined with fiscal deficits. Clearly these countries present evidence of a high level of capital mobility. One cannot conclude these countries are closed off to capital markets. This brings into question the interpretation and usefulness of Feldstein and Horioka's original model.

Traditional saving-investment regressions provide little use for measuring capital mobility. The literature has consistently adopted the view that regressions between saving and investment rates, in levels, measure the existence of a long-run budget constraint. Caution needs to be used when interpreting high savings coefficient, from the Feldstein-Horioka model, as evidence against capital mobility. A more appropriate representation is an error correction model which jointly models the short-run dynamics and long-run relationship.

Vector Error Correction Models

A number of authors have argued using the traditional Feldstein-Horioka equation to model the saving-investment relationship will only pick up the long-run relationship. Because a country faces long-run borrowing constraints saving and investment rates should be perfectly correlated. If a country is currently experiencing a large external imbalance, in the future the imbalance needs to be offset. This implies saving and investment rates should move together in the long-run. This is clearly evident in a number of countries above.

There are a number of methods to detect a long-run relationship. The most common approach has been Engle-Granger's two-step procedure. First step involves testing if saving and investment rates are non-stationary, if so, step two applies a unit root test on the residuals from equation II.3. Miller (1988) was the first to test for cointegration but not to measure capital mobility. Miller was interested in testing if saving-investment regressions are spurious. Miller found saving and investment rates were cointegrated prior to 1973 but not cointegrated afterward. He interpreted this as evidence of increasing capital mobility. Instead of focusing on the savings coefficient to infer capital mobility, it became the norm to focus on the stationarity properties of the residuals. Saving and investment rates were both found non-stationary and if the residuals are stationary (non-stationary) then capital is mobile (immobile). The process of estimating the cointegrating relationship started with Engle-Granger's two step method or Johansen's maximum likelihood procedures. Currently the most commonly used cointegration tests is through the estimation of an error correction model. Coakley et al. (1996) and Jansen (1996) independently show the error correction representation is the most appropriate model for testing the saving-investment relationship.

The error correction model offers a number of advantages over the basic two variable regression. A general error correction model allows for modeling short and long-run dynamics and tests for a cointegrating relationship. An important point of discussion is the stationary properties of saving and investment rates. A number of authors have documented both variables follow a non-stationary path. This result is controversial and incorrectly motivates the use of an error correction model.[7]

[7]Chapter 3 shows saving and investment rates are more likely to follow a stationary path when tested for unit roots allowing for more powerful tests and structural breaks.

Because of the uncertainty surrounding the properties of saving and investment rates it is important to note that adequately determining the stationarity properties of both variables is not a necessary condition for using the error correction representation. Nevertheless, it is common practice to use an error correction model with non-stationary data. The link between error correction models and cointegration dates back to Engle and Granger (1987). The Granger representation theorem states that for any set of I(1) variables, error correction and cointegration are equivalent representations (Enders 2004). Thus, a precursor to the error correction model was appropriate unit root testing to verify both variables are I(1). Despite the common link between error correction models and cointegration, the error correction method can be used for stationary variables.

Banerjee et al. (1993) model the error correction model from a more general autoregressive distributive lag model which makes no underlying assumptions over the stationary properties for each variable. In the context of saving and investment rates, a basic ARDL(1,1) model can be characterized as:

$$i_t = \alpha_0 + \alpha_1 i_{t-1} + \beta_0 s_t + \beta_1 s_{t-1} + \varepsilon_t. \tag{II.6}$$

The first step in transforming equation II.6 is to take the first difference of i_t:

$$\Delta i_t = \alpha_0 + (\alpha_1 - 1) i_{t-1} + \beta_0 s_t + \beta_1 s_{t-1} + \varepsilon_t. \tag{II.7}$$

Then add and subtract $\beta_0 s_{t-1}$ from the right hand side:

$$\Delta i_t = \alpha_0 + (\alpha_1 - 1) i_{t-1} + \beta_0 \Delta s_t + (\beta_0 + \beta_1) s_{t-1} + \varepsilon_t. \tag{II.8}$$

Finally add and subtract $(\alpha - 1)s_{t-1}$ from the right hand side:

$$\Delta i_t = \alpha + \gamma(s_{t-1} - i_{t-1}) + \beta \Delta s_t + \delta s_{t-1} + \varepsilon_t \tag{II.9}$$

where $\gamma = (\alpha_1 - 1)$, $\beta = \beta_0$, $\alpha = \alpha_0$, and $\delta = \beta_1 + \beta_0 + \alpha_1 - 1$.

Jansen (1996) argues saving and investment should be tied together as a condition of the long-run budget constraint. Following Levy (1996), Jansen assumes saving and investment should cointegrate with a (1, -1) vector which will correspond with a unit coefficient from equation II.3. The short-run relationship exists if the hypothesis $\beta = 0$ is rejected. The long run relationship exists if $\gamma = 0$ is rejected. Furthermore, equation II.9 nests equation II.3, which can be seen by rearranging equation II.9 and jointly setting $\gamma = 1$ and $\beta + \delta = 1$ and $\gamma = 1$. In the long-run saving and investment rates will have the following cointegrating relationship:

$$\alpha + \gamma(\bar{s} - \bar{i}) + \delta(\bar{s}) = 0. \tag{II.10}$$

In equation II.10 bars denote long-run values. The cointegrating relationship is given by $(1 + \delta/\gamma, -1)$. Additionally, if $\delta = 0$ the current account, $(\bar{s} - \bar{i})$, will be stationary and equal $-\alpha/\gamma$. A nice feature of the error correction model is the estimation of the speed of adjustment parameter, γ. In terms of the saving-investment model, γ models the time frame for which a country can run an external deficit/surplus before expecting a return to equilibrium.

Coakley et al. also use the error correction model to focus on the cointegrating relationship between saving and investment rates. Their argument is straightforward and parallels Jansen (1996). Saving and investment rates are both characterized as I(1) variables, but must move together over time. Countries are faced with a solvency constraint that prevents debt from exploding. By definition the difference between saving and investment is the current account which translates into both variables being cointegrated with a unit coefficient.

The results for the error correction model are presented in table 2.3. The models are selected according the Akaike Information Criterion, and are robust to other information measures. The final model is free of serial correlation, ARCH effects, non-normality, and heteroscedasticity.[8] The three key parameters of interest are β, the short-run relationship, γ, the long-run relationship, and δ, current account stationarity. As seen in the table the estimated values of β closely resemble the values in table 2.2. Again only Ireland, Luxembourg, and Norway have a short-run savings coefficient insignificant from zero and 16 countries fail to reject the coefficient equals one. These results emphasize small open countries are more likely to produce a lower saving's coefficient than large closed countries. The large number of countries with a saving's coefficient near unity is extremely disconcerting. Using a longer, updated data should produce a lower correlations. Shown below, stability tests find most countries exhibit unstable parameters.

The next parameter of interest, γ, tests for a cointegrating relationship between saving and investment rates and also captures the speed of adjustment. For large

[8]The results for each diagnostic test are available from the author.

samples Kremers et al., (1992) show the associated t values follows the standard normal distribution. For small samples they recommend using the critical values from the Dickey Fuller distribution. Using the Dickey Fuller critical values $\gamma = 0$ is rejected, i.e. a long-run relationship exists, for nine countries at the 1% level, five countries at the 5% level, and two countries at the 10% level. Austria, Denmark, Germany, Greece, Ireland, Luxembourg, Norway, Sweden, Switzerland, and United States fail to reject the non-cointegration hypothesis. Interestingly, three countries that failed to reject non-cointegration, Ireland, Luxembourg, and Norway, also have saving's coefficients insignificant from zero. These results are very similar to Jansen (1996), but vastly different from Leachman (1994). The number of cointegrating series matches that of Jansen, but the individual countries differ. In the end I can conclude with relative certainty 14 countries have a cointegrating relationship between saving and investment rates.

In addition to determining whether or not a cointegrating relationship exists, γ also measures the speed of adjustment. Countries will experience a quick (slow) adjustment to a long-run equilibrium for large (small) values of γ. A quick adjustment can be interpreted as the inability to sustain a current account imbalance. Surprisingly I find Australia, New Zealand, and Turkey lack the ability to sustain current account imbalances. Given the nature of Australia's external position (large current account deficit) they should expect a relatively quick adjustment. Countries that have a slow adjustment are Denmark, Germany, Norway, Sweden, and United States. These countries will experience a gradual reversal.

It is worth mentioning the results for δ. Testing if $\delta = 0$ is equivalent to testing if the current account is stationary. If so, the current account fluctuates around $-\alpha/\gamma$ in the long-run. Jansen finds δ significant for Australia, Canada, Finland, Ireland, Netherlands, and Switzerland. With the exception of Australia the other five countries are running sizeable current account surpluses. The United States rejects $\delta = 0$ at the 10% level, given the recent trend in the US deficit, with updated data the current account will likely be non-stationary. Comparing these results to Jansen (1996) shows over the last decade current account balances have experienced persistent growth. This goes against the common view that countries are bound by an intertemporal budget constraint or at a minimum have not reached a turning point in their imbalances.

The error correction model provides useful information into current account dynamics, and also allows for measuring capital mobility in a variety of ways. First is the failure to reject non-cointegration. If saving and investment rates do not move together, then capital is mobile in the Feldstein-Horioka view. If non-cointegration is rejected then the degree of capital mobility depends on the stationarity of the current account. If the current account is stationary then the degree of capital mobility is ambiguous. This result confirms the existence of a long-run budget constraint. If the current account is found non-stationary then capital mobility exists. Lastly the degree of capital mobility can be measured through the short-run change in saving rates on investment rates if there is evidence of a cointegrated relationship and a stationary current account.

- Case 1 ($\gamma = 0$): Austria, Denmark, Finland, Germany, Greece, Ireland, Luxembourg, Norway, Sweden, Switzerland, United States.
- Case 2 ($\gamma \neq 0$ and $\delta \neq 0$): Australia, Canada, Denmark, and Netherlands.
- Case 3 (($\gamma \neq 0$ and $\delta = 0$ and β small): New Zealand.

The countries not displaying evidence of capital mobility are Belgium, France, Iceland, Italy, Japan, Portugal, Spain, Turkey, and United Kingdom. These results are also consistent with a high savings coefficient found in equation II.3.

The error correction framework is useful for measuring both the short-run and long-run dynamics but given the recent emphasis on the long-run relationship a number of problems occur. Standard tests for cointegration rely on the underlying variables being integrated of order one. In some cases saving and investment rates reject the non-stationary hypotheses. In the following chapter I show through use of more powerful unit root tests and after controlling for structural breaks both variables are more likely to reject non-stationarity. Nevertheless given the large number of contradicting cointegration results one extension is the proposed autoregressive distributive lag model by De Vita and Abbott (2002). The autoregressive distributive lag model does not depend on the assumptions that both variable are integrated of order one.

Autoregressive Distributive Lag Models

In the previous section I presented results that show 14 countries fail to reject the non-cointegration hypothesis. This result is displeasing. Cointegration tests should confirm the existence of a binding long-run budget constraint. A possible cause for the failure to find a cointegrating relationship for a large sample of countries stems from the inability of unit root tests to accurately detect if a series is trend or level stationary.

Following De Vita and Abbott (2002), Corbin (2004) and Kollias et al., (2006) the following ARDL(p,q) model is estimated:

$$i_t = \alpha_0 + \beta_1 i_{t-1} + \beta_2 s_{t-1} + \sum_{i=1}^{p} \gamma_i \Delta i_{t-i} + \sum_{i=1}^{q} \delta_i \Delta s_{t-i} + u_t. \qquad \text{(II.11)}$$

This model is a slight variation on the ARDL model used above to derive the error correction representation. The test proposed by Pesaran and Shin (1999) is based on two separate bounds tests. The two tests are a F-statistic to test the joint significance for the lagged variables, i.e. $\beta_1 = \beta_2 = 0$, and a t-test for the null hypothesis $\beta_1 = 0$. Under the alternative hypothesis, $\beta_1 \neq 0$ and $\beta_2 \neq 0$, there is a long-run relationship defined as:

$$i_t = \theta_0 + \theta_1 s_t + \nu_t \qquad \text{(II.12)}$$

where $\theta_0 = -\alpha_0/\beta_1$, $\theta_1 = -\beta_2/\beta_1$, and ν_t is the error term. Equation II.12 parallels equation II.3 estimated in section 2.

There are three outcomes within the ARDL bounds testing methodology. If the sample test statistics are below the lower bound of the critical values, the null hypothesis cannot be rejected, no level relationship exists, and the variables are I(0). If the test statistic exceeds the upper bound then a long-run relationship is present and both variables are I(1). The bounds testing procedure is sufficient as long as the computed F-statistic lies outside the critical bounds. For cases in which the test statistics lie inside the critical values, no conclusive inference is possible.[9]

Results for equation II.11 are presented in table 2.4. Again the sample is 24 OECD countries from 1950-2004. Equation II.11 was estimated by OLS, allowing up to three lag differences for both variables. The final models were selected by Akaike information criterion (AIC) and Schwartz information criterion (SIC). The final model is free of serial correlation, ARCH effects, non-normality, and heteroscedasticity.[10] Unlike the unrestricted error correction model above, the ARDL model does not have a direct long-run interpretation. The results for the existence of a long-run relationship, equation II.12, are also presented in table 2.5.

The long-run relationship between saving and investment rates is established when the values for the F-statistic and t-statistic lie above the upper critical values. These results are presented in table 2.5. At the 10% level Australia, Canada,

[9]For critical values see Pesaran et al. (2001) Tables C1.iii and C2.ii.
[10]The results for each diagnostic test are available from the author.

France, Iceland, New Zealand, Portugal, Spain, Turkey, and United Kingdom have a long-run relationship, saving and investment rates are cointegrated. With the exception of Belgium and United States, the remaining countries fail to reject non-cointegration. This suggests a number of countries have been able to sustain current account deficits (or surpluses). When a long-run relationship is found significant, then θ_1 can be interpreted in the same light as the degree of capital mobility from the original Feldstein-Horioka model. The long-run coefficients range from a low of 0.075 (Portugal) and a high of 0.957 (Iceland). It is also important to note Canada and United Kingdom have high levels of capital mobility while Australia, France, Spain, and Turkey have low measures of capital mobility. New Zealand has an intermediate level of capital mobility.

Table 2.5 also reports the F statistic for $-\beta_1 = \beta_2$, which tests for current account stationarity. Failure to reject the null hypothesis $-\beta_1 = \beta_2$ and for values of θ_1 near unity implies the current account solvency conditions holds. The null hypothesis is rejected for small values of the F statistic, the 5% critical value is $F[1, 55] = 4.02$. The current account is found stationary for all countries except Canada, Ireland, Japan, Portugal, United Kingdom, and United States. The current account solvency condition holds for Australia, Austria, Finland, France, Germany, Greece, Iceland, Italy, Netherlands, Norway, Spain, Sweden, Switzerland, and Turkey. The current account solvency condition does not imply capital immobility, it simply states that over time these countries have external balances that return to equilibrium.

Similar to the error correction model, the autoregressive distributive lag model has a number of possibility outcomes that can be interpreted in terms of capital mobility. Capital mobility can be inferred if saving and investment are not cointegrated. If saving and investment rates are cointegrated, capital mobility exists if the current account is non-stationary. Lastly, if saving and investment rates are cointegrated and the current account is stationary then a necessary condition for capital mobility is a small short-run saving-investment correlation coefficient.

- Case 1 ($\beta_1 = 0$ and $\beta_2 = 0$): Denmark, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Norway, and Sweden
- Case 2 ($\beta_1 \neq 0$, $\beta_2 \neq 0$, and $\beta_1 + \beta_2 \neq 0$): Japan, United States
- Case 3 ($\beta_1 \neq 0$, $\beta_s \neq 0$, $\beta_1 + \beta_2 = 0$, and small values of β): New Zealand

These results are vastly different from those presented under the error correction representation. Fewer countries display evidence of capital mobility. A number of countries display mixed evidence in support of capital mobility. Countries that have some evidence of capital mobility, imperfect capital mobility, include: Australia, Belgium, Canada, Finland, Portugal, and United Kingdom. Countries that display little evidence of capital mobility are Austria, France, Iceland, Spain, Switzerland, and Turkey.

A summary of the results applied to a capital mobility interpretation is presented in table 2.7. The two variable OLS models provide evidence of the degree of capital mobility and how capital mobility has changed over time. The VEC and ARDL models offer an interpretation in the form of high, intermediate, or low degrees of capital mobility. High capital mobility is assumed when a country is found to reject any of the three cases listed above. Intermediate capital mobility is assumed when saving and investment rates have a long-run relationship, a stationary current account, but a savings coefficient significantly lower than one. Combined the tests show a high level of capital mobility for most countries. France, Spain, and Turkey have little to no capital mobility. Belgium and Iceland have a low measure of capital mobility. Portugal and United Kingdom have an intermediate degree of capital mobility. A high level of capital mobility is found for Denmark, Germany, Greece, Ireland, Luxembourg, New Zealand, Norway, Sweden, and United States.

These results show that in addition to the small, open country argument, large countries (Germany, Japan, United Kingdom and United States) show evidence of capital mobility. Nevertheless one cannot help but question the validity of these results under the assumptions of parameter constancy. The previous models have assumed a constant measure of capital mobility and fail to account for known structural changes. It is unreasonable to suspect a constant saving-investment relationship following the breakdown of the Bretton Woods system, global recessions in the early 1970's and 1980's and the investment boom in the 1990's. In addition to global effects there are country specific factors that may lead to varying regimes of capital mobility. These regimes can include changes in exchange rate regimes (European Monetary System), country specific business cycles, and changes in domestic policy. The next section will test each regression for parameter constancy following Elliott and Müller (2006).

Stability Tests

I have shown saving and investment regressions can provide insight into capital mobility and current account adjustment. Regardless of the interpretation it is critical to correctly model the relationship. The previous sections provide a thorough review, updated the literature, and presented the results with emphasis on capital mobility in regards to traditional OLS, VEC, and ARDL models. To date only a few authors have been concerned with the possibility of instability. Ozman and Parmaksiz (2003a and 2003b) and Kejriwal (2008) have tested the long-run relationship for structural breaks. Instead of testing the cointegration relationship for instability, I adopt a more general approach that is applicable to linear time series models. Elliott and Müller (2006) develop a stability test for general parameter constancy against a very general alternative hypothesis. More importantly they have devised a relatively simple test statistic that avoids searching over high dimensions when many breaks are present. The null hypothesis is rejected for small values for their test statistic, $\widehat{qLL}$.

The most common approach to testing for parameter stability are structural break tests, recursive residual tests, and rolling regressions. The most common tests for a single structural shift comes from Chow (1960), where the test involves sample splitting and testing for parameter constancy across each grouping. Brown, Durbin, and Evans (1975) recognized the need to test for more general parameter constancy and proposed a recursive residual test that uses the cumulative sum of the residuals (and squared residuals). The CUSUM method tests for instability in the intercept alone and the CUSUM-squared approach detects instability in the variance of the regression error (Hansen, 1992). Each of the these test are useful when the researcher is interested in testing for a specific type of instability. Elliott and Müller (2006) examine parameter instability under a single unified framework. They develop a single test statistic for processes that include breaks that occur in a random fashion, serial correlation in the changes of the coefficients, a clustering of break dates, time varying parameters, and others forms of instability. Their main results are dependent on the disturbances following a normal distribution, if so then small sample efficient tests in this broad setup are equivalent.

The Elliott-Müller test statistic is considered over previous stability tests because if offers, "The equivalence of power over many models means that there is little point in deriving further optimal tests for particular processes in our set (p.908)." Furthermore this means the specific form of parameter instability does not need to be specified a priori. Another benefit of the Elliott-Müller approach is the computation of Quasi-Local Level ($\widehat{qLL}$) test statistic is straightforward. The test statistic, $\widehat{qLL}$, remains valid for very general specifications of the error term and covariates. The computation requires no more than (k + 1) ordinary least squares regressions for a model with k covariates, in contrast to many approaches that require computations for each possible combinations of break points. Additionally, Elliott-Müller show their test statistic requires no trimming of the data and has superior size control in small samples (particularly under heteroscedastic disturbances).

In the context of saving-investment regressions testing for stability has a number of important consequences. In the previous section a few instances arose, abnormal results, in which one has to question the use of a constant parameter model. First and foremost using a data set spanning 50 years is bound to have some form of structural break or time varying parameters. In this time period the degree of capital mobility has not remained constant, countries may have non-stationary current account balances over the medium run, the long-run relationship could shift as a result of changes in policy, and global factors will affect current account dynamics. No matter if one views saving-investment regressions as a means of testing for capital mobility, current account solvency, or the existence of a long-run budget constraint, each model needs to be accurately measured.

The results for Elliott-Müller's $\widehat{qLL}$ are presented in table 2.6. The null hypothesis of parameter stability is rejected for small values of $\widehat{qLL}$. Surprisingly the results for the traditional Feldstein-Horioka regression show little evidence of parameter instability. Every country fails to reject the null of parameter stability at the 10% level. The results are much different for the error correction and autoregressive distributive lag models. When the saving-investment regression is estimated in the error correction framework ten countries fail to reject parameter stability. Some of the notably countries experiencing parameter instability are Australia, Germany, Japan, United Kingdom, and United States. Using the stability test on the ARDL regressions estimated previously seven countries reject stability.

The purpose of testing the previously estimated regressions for stability is to confirm the basic hypothesis that capital mobility has changed over time and to provide the motivation for further analysis. Future sections will test for the presence of a unit roots and level shifts in either variable.

Conclusion

The goal of this chapter was to provide a short review and update the literature associated with time series analysis of the saving-investment relationship. I was the first to extend the autoregressive distributive lag model to a larger OECD sample and test all three regressions for stability. In the end the results suggest that the saving-investment relationship has declined over time, but still remains statistically significant for a number of countries. Estimation of the two variable model found a number of countries with intermediate measures of capital mobility. When saving rates were interacted with a time trend it became clear the relationship is weakening. The next extension came with the estimation of an error correction model. The error correction model presented results for the short-run and long-run relationship. The short-run coefficient shows considerable evidence against the perfect capital mobility hypothesis. The long-run relationship was present for only a handful of countries. The inability to reject the non-cointegration hypothesis suggests a number of countries are able to run sizeable current account imbalances, including the United States. There is evidence of capital mobility for 16 countries. One of the criticisms of the error correction model is the inability to accurately determine the integration properties for both saving and investment rates. The use of the autoregressive distributive lag model is robust to the underlying variables being I(0) or I(1). Using the autoregressive distributive lag model allowed for the detection of capital mobility under a number of cases. In the end 12 countries display evidence of perfect capital mobility and another six countries have imperfect capital mobility. Lastly, I presented results that suggests each of the previous models may be unstable. This result is not surprising and needs to be addressed further.

Table 2.2. Saving-Investment Regressions

Country	N	Equation II.3	Equation II.4		Equation II.5		
		β	β	γ	β	δ_1	δ_2
Australia	55	0.606 (0.185)	0.616 (0.242)	0.018 (0.138)	0.609 (0.219)	0.060 (0.500)	-0.076 (0.691)
Austria	55	0.769 (0.178)	0.931 (0.150)	-0.193 (0.062)	0.631 (0.150)	0.665 (0.317)	-1.423 (0.478)
Belgium	55	0.585 (0.114)	0.726 (0.083)	-0.317 (0.044)	0.660 (0.093)	0.271 (0.228)	-1.023 (0.364)
Canada	55	0.364 (0.072)	0.628 (0.122)	-0.168 (0.060)	0.643 (0.124)	-0.097 (0.167)	-0.135 (0.276)
Denmark	55	0.468 (0.105)	1.160 (0.097)	-0.659 (0.072)	0.993 (0.087)	0.626 (0.321)	-2.123 (0.507)
Finland	55	1.544 (0.154)	1.296 (0.150)	-0.331 (0.115)	0.806 (0.110)	1.313 (0.232)	-3.233 (0.435)
France	55	0.942 (0.069)	0.951 (0.071)	-0.029 (0.046)	0.656 (0.082)	0.916 (0.185)	-1.640 (0.328)
Germany	35	1.218 (0.115)	0.706 (0.060)	-1.055 (0.111)	0.522 (0.074)	1.853 (0.604)	-3.587 (0.775)
Greece	54	0.971 (0.041)	0.930 (0.037)	0.514 (0.115)	0.983 (0.085)	0.227 (0.454)	0.549 (0.722)
Iceland	55	0.960 (0.103)	0.808 (0.096)	-0.399 (0.093)	0.767 (0.170)	-0.279 (0.517)	-0.265 (1.205)
Ireland	55	0.066 (0.042)	0.449 (0.260)	-0.595 (0.365)	-0.141 (0.294)	2.379 (1.107)	-3.910 (1.422)
Italy	55	1.072 (0.047)	0.866 (0.051)	-0.381 (0.063)	0.767 (0.068)	0.003 (0.300)	-0.790 (0.391)
Japan	55	0.912 (0.025)	0.964 (0.029)	-0.086 (0.028)	0.876 (0.095)	0.226 (0.342)	-0.477 (0.502)
Luxembourg	55	0.209 (0.079)	0.273 (0.085)	-0.446 (0.079)	0.259 (0.085)	-0.700 (0.680)	0.440 (1.100)
Netherlands	55	1.313 (0.250)	1.064 (0.194)	-0.563 (0.103)	0.908 (0.171)	-0.003 (0.300)	-1.020 (0.507)
New Zealand	55	0.460 (0.133)	0.428 (0.139)	-0.193 (0.076)	0.398 (0.135)	-0.428 (0.372)	0.406 (0.644)
Norway	55	0.233 (0.364)	0.262 (0.197)	-0.796 (0.069)	0.147 (0.184)	0.578 (0.244)	-2.439 (0.436)
Portugal	55	0.533 (0.090)	0.409 (0.083)	0.640 (0.108)	0.166 (0.146)	2.318 (0.623)	-2.920 (1.050)
Spain	55	1.114 (0.074)	1.129 (0.094)	-0.022 (0.063)	1.238 (0.139)	-0.347 (0.334)	0.536 (0.536)
Sweden	55	0.727 (0.161)	0.757 (0.096)	-0.520 (0.060)	0.750 (0.063)	0.719 (0.144)	-2.161 (0.244)
Switzerland	55	0.960 (0.111)	1.405 (0.111)	-0.423 (0.042)	1.209 (0.134)	0.168 (0.233)	-0.971 (0.357)
Turkey	55	1.098 (0.086)	0.803 (0.201)	0.502 (0.274)	0.514 (0.171)	2.289 (0.713)	-2.721 (1.266)
United Kingdom	55	0.662 (0.087)	0.618 (0.082)	0.132 (0.056)	0.720 (0.181)	-0.201 (0.515)	0.570 (0.851)
United States	55	0.517 (0.151)	0.726 (0.109)	0.379 (0.042)	0.781 (0.095)	-0.139 (0.121)	0.939 (0.233)

Huber/White standard errors are calculated and are in parentheses

γ and δ_1 are scaled by 100 and δ_2 is scaled by 10,000

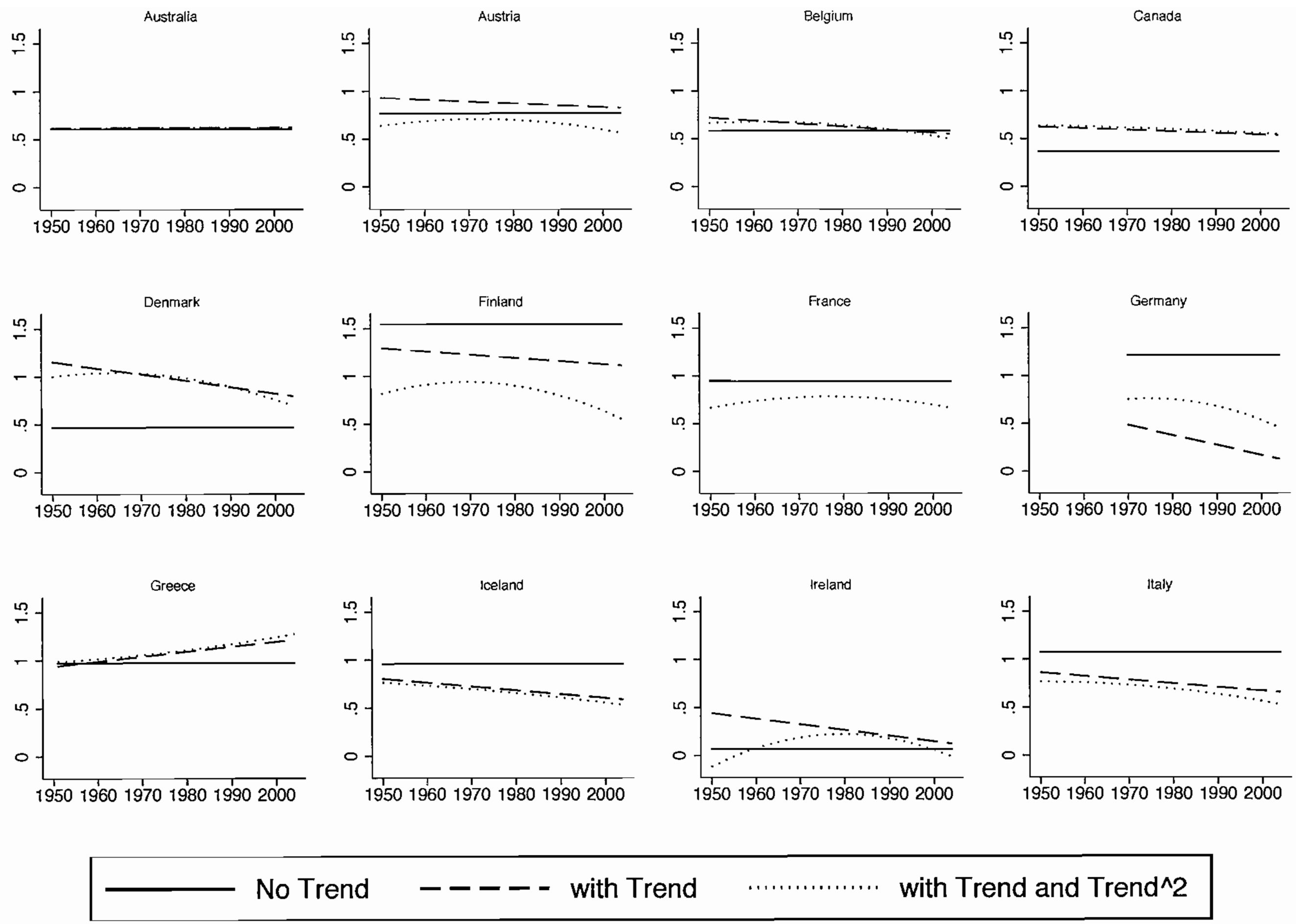

Figure 2.1. Saving Coefficient, Australia - Italy

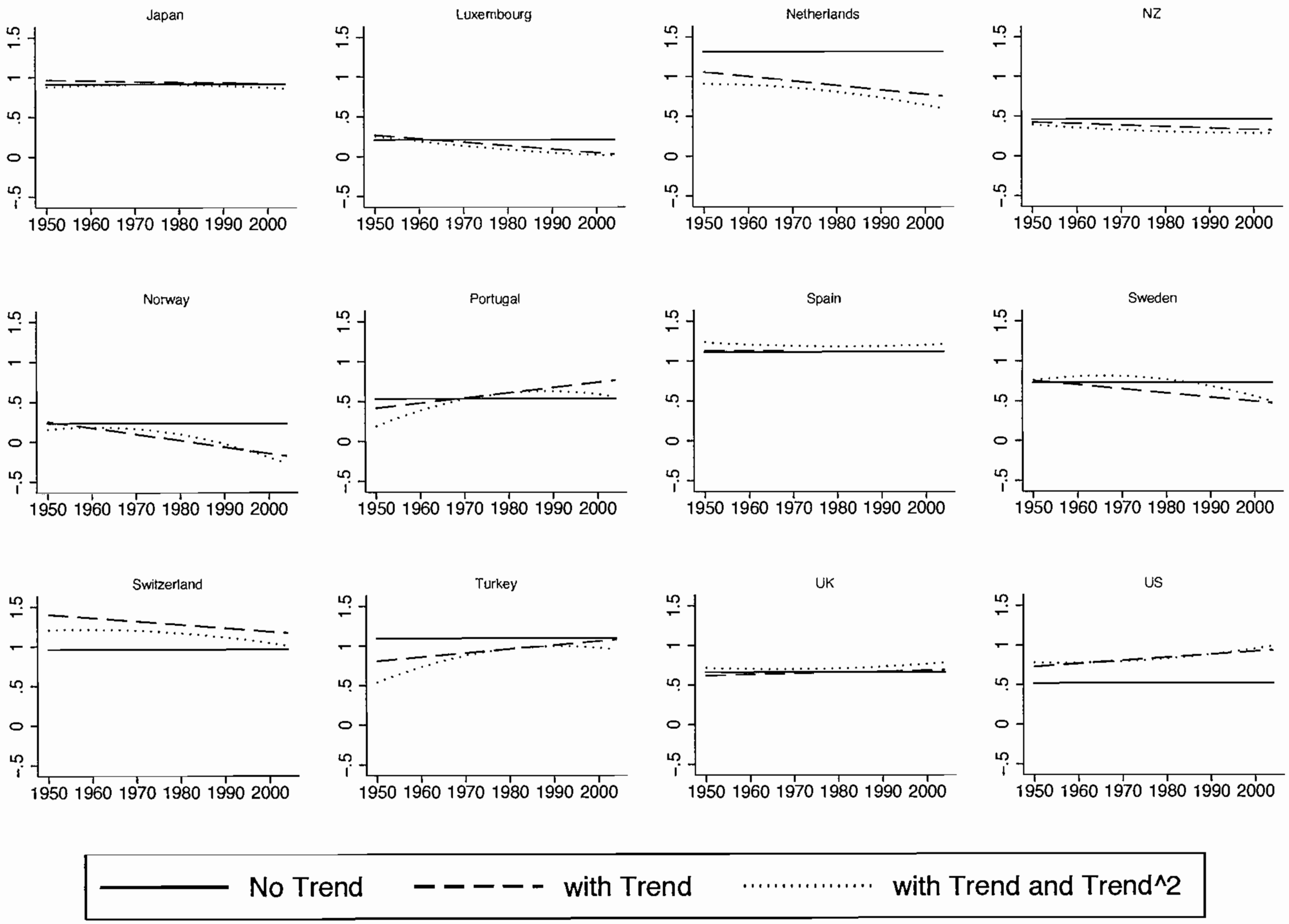

Figure 2.2. Saving Coefficient, Japan - U.S.

Table 2.3. Vector Error Correction Regressions

Country	N	α	β	γ	δ	Δi_{t-1}	Δi_{t-2}	Δs_{t-1}	Δs_{t-2}	R^2
Australia	52	6.667 (2.865)	0.744 (0.139)	0.856 (0.161)	-0.228 (0.112)	0.038 (0.106)		0.199 (0.166)	0.303 (0.134)	0.628
Austria	52	-3.296 (2.563)	0.966 (0.141)	0.191 (0.130)	0.122 (0.099)	-0.038 (0.129)	-0.297 (0.086)	-0.101 (0.185)		0.693
Belgium	54	-0.613 (2.121)	0.745 (0.122)	0.230 (0.087)	0.009 (0.084)					0.504
Canada	54	5.755 (2.840)	0.719 (0.124)	0.372 (0.120)	-0.238 (0.113)					0.566
Denmark	53	-0.211 (2.145)	0.837 (0.175)	0.066 (0.081)	0.001 (0.088)	-0.226 (0.148)		0.414 (0.216)		0.470
Finland	54	-11.393 (2.872)	0.875 (0.119)	0.272 (0.070)	0.332 (0.085)					0.574
France	54	-0.728 (1.474)	0.723 (0.124)	0.364 (0.101)	0.028 (0.060)					0.519
Germany	32	-2.806 (2.291)	0.770 (0.170)	-0.065 (0.088)	0.097 (0.091)	0.172 (0.193)	-0.541 (0.212)	-0.085 (0.221)	0.441 (0.233)	0.640
Greece	53	1.387 (0.863)	0.920 (0.081)	0.186 (0.085)	-0.009 (0.030)					0.735
Iceland	52	-0.002 (3.017)	0.650 (0.199)	0.480 (0.185)	0.020 (0.111)	0.031 (0.164)	-0.254 (0.145)	-0.295 (0.230)	0.434 (0.217)	0.501
Ireland	54	4.146 (1.858)	-0.080 (0.152)	0.198 (0.082)	-0.181 (0.084)					0.107
Italy	54	-1.041 (1.290)	0.817 (0.160)	0.288 (0.097)	0.033 (0.046)					0.402
Japan	52	1.151 (0.937)	0.958 (0.153)	0.575 (0.140)	-0.055 (0.030)	0.222 (0.138)		-0.267 (0.164)	0.157 (0.082)	0.681
Luxembourg	52	3.391 (2.515)	-0.167 (0.105)	0.142 (0.089)	-0.125 (0.081)	0.010 (0.136)		0.106 (0.110)	0.290 (0.106)	0.329
New Zealand	54	1.414 (3.936)	0.341 (0.151)	0.604 (0.122)	-0.052 (0.170)					0.409
Netherlands	54	-9.016 (3.731)	0.969 (0.222)	0.308 (0.081)	0.283 (0.128)					0.360
Norway	54	-1.645 (5.813)	-0.085 (0.193)	0.092 (0.063)	0.034 (0.166)					0.058
Portugal	53	3.806 (2.051)	0.598 (0.123)	0.300 (0.094)	-0.112 (0.104)	0.186 (0.111)				0.496
Spain	53	-0.796 (1.585)	0.765 (0.129)	0.357 (0.084)	0.056 (0.068)	0.401 (0.102)				0.554
Sweden	53	-2.632 (2.172)	0.747 (0.131)	0.006 (0.064)	0.098 (0.086)	-0.233 (0.146)		0.351 (0.159)		0.465
Switzerland	53	-5.935 (2.582)	1.685 (0.151)	0.145 (0.075)	0.166 (0.080)	0.147 (0.071)				0.761
Turkey	54	0.525 (0.843)	0.869 (0.108)	0.668 (0.128)	0.119 (0.074)					0.644
United Kingdom	52	3.233 (1.573)	0.606 (0.145)	0.415 (0.109)	-0.155 (0.084)	0.204 (0.126)		-0.134 (0.159)	-0.384 (0.135)	0.494
United States	52	-3.479 (2.042)	1.136 (0.085)	-0.059 (0.062)	0.178 (0.102)	0.097 (0.153)	-0.149 (0.071)	-0.324 (0.163)		0.851

Standard errors are in parentheses, critical values for γ follow DF distribution (-3.57, -2.92, and -2.60)
Models are selected according to Akaike Information Criterion.

Table 2.4. Autoregressive Distributive Lag Regressions

Country	N	α_0	β_1	β_2	γ_1	γ_2	δ_1	δ_2	R^2
Australia	54	0.632 (0.343)	-1.049 (0.121)	0.841 (0.143)					0.607
Austria	52	0.350 (0.334)	-0.411 (0.178)	0.274 (0.205)	0.236 (0.173)	-0.333 (0.122)	-0.347 (0.257)		0.373
Belgium	54	0.467 (0.253)	-0.298 (0.113)	0.102 (0.112)					0.132
Canada	52	1.530 (0.454)	-0.797 (0.190)	0.178 (0.117)	0.197 (0.208)	0.386 (0.186)	0.140 (0.213)	-0.507 (0.216)	0.387
Denmark	53	0.348 (0.241)	-0.157 (0.096)	0.011 (0.096)	-0.330 (0.177)		0.591 (0.258)		0.211
Finland	52	-0.960 (0.489)	-0.289 (0.115)	0.563 (0.231)	0.133 (0.199)	-0.243 (0.172)	-0.132 (0.283)	-0.311 (0.231)	0.263
France	54	0.148 (0.182)	-0.444 (0.129)	0.383 (0.142)					0.192
Germany	32	0.207 (0.269)	0.029 (0.116)	-0.132 (0.167)	0.286 (0.255)	-0.756 (0.275)	-0.133 (0.295)	0.428 (0.310)	0.334
Greece	53	0.247 (0.161)	-0.130 (0.160)	0.055 (0.165)					0.045
Iceland	53	0.120 (0.320)	-0.510 (0.138)	0.488 (0.184)			-0.587 (0.202)		0.302
Ireland	54	0.398 (0.181)	-0.194 (0.081)	0.018 (0.035)					0.102
Italy	52	0.095 (0.159)	-0.183 (0.124)	0.144 (0.147)	-0.184 (0.164)		0.391 (0.239)	0.423 (0.205)	0.238
Japan	53	0.250 (0.132)	-0.467 (0.206)	0.377 (0.189)	0.090 (0.124)				0.119
Luxembourg	52	0.285 (0.253)	-0.151 (0.090)	0.039 (0.062)	0.034 (0.138)		0.121 (0.111)	0.315 (0.107)	0.291
New Zealand	54	0.650 (0.335)	-0.648 (0.125)	0.375 (0.137)					0.349
Netherlands	52	0.324 (0.420)	0.018 (0.105)	-0.134 (0.212)	-0.079 (0.130)	-0.450 (0.124)	0.004 (0.244)	0.430 (0.226)	0.273
Norway	54	-0.267 (0.527)	-0.093 (0.063)	0.155 (0.146)					0.055
Portugal	53	0.723 (0.203)	-0.339 (0.104)	0.025 (0.110)			0.385 (0.138)		0.309
Spain	53	0.206 (0.197)	-0.354 (0.110)	0.292 (0.146)	0.255 (0.129)				0.224
Sweden	52	-0.063 (0.274)	-0.067 (0.078)	0.085 (0.122)	-0.172 (0.180)	-0.273 (0.139)	0.386 (0.210)		0.193
Switzerland	53	0.467 (0.441)	-0.320 (0.132)	0.153 (0.193)			0.302 (0.239)		0.146
Turkey	54	0.261 (0.120)	-0.599 (0.191)	0.517 (0.231)					0.182
United Kingdom	52	0.559 (0.171)	-0.425 (0.127)	0.142 (0.115)	0.179 (0.146)		-0.016 (0.182)	-0.365 (0.157)	0.297
United States	53	1.279 (0.288)	-0.201 (0.114)	-0.435 (0.139)	0.250 (0.136)				0.287

Standard errors are in parentheses

Table 2.5. ARDL Bounds Test, F and t Statistics

Country	F-Statistic	t-Statistic	θ_0	θ_1	$-\beta_1 = \beta_2$
Australia	39.331*	-8.694*	0.603(0.30)	0.802(0.12)	2.442
Austria	2.943***	-2.309***	0.851(0.84)	0.665(0.32)	1.125
Belgium	3.862***	-2.647**	1.568(0.81)	0.342(0.31)	3.809
Canada	8.830*	-4.201*	1.919(0.35)	0.223(0.13)	11.663
Denmark	1.614***	-1.640***	2.221(1.45)	0.073(0.59)	2.157
Finland	3.305***	-2.513***	-3.326(1.40)	1.949(0.41)	3.580
France	6.076*	-3.452*	0.334(0.41)	0.862(0.16)	0.692
Germany	0.479***	0.251***	-0.709(2.90)	4.521(4.07)	0.938
Greece	1.178***	-0.814***	1.896(1.75)	0.418(0.80)	1.855
Iceland	6.904*	-3.703*	0.237(0.63)	0.957(0.23)	0.035
Ireland	2.912***	-2.408***	2.050(0.38)	0.094(0.17)	4.506
Italy	1.603***	-1.469***	0.521(1.01)	0.787(0.36)	0.473
Japan	3.237***	-2.272***	0.535(0.30)	0.807(0.09)	4.301
Luxembourg	1.419***	-1.676***	1.890(1.32)	0.259(0.36)	1.861
New Zealand	13.651*	-5.176*	1.002(0.45)	0.579(0.19)	3.597
Netherlands	0.360***	0.171***	-1.795(9.51)	7.433(34.68)	0.667
Norway	1.472***	-1.476***	-2.883(6.48)	1.674(1.81)	0.171
Portugal	6.884*	-3.253*	2.133(0.50)	0.075(0.31)	9.166
Spain	5.765*	-3.207*	0.583(0.59)	0.825(0.25)	0.542
Sweden	0.418***	-0.857***	-0.942(4.37)	1.263(1.69)	0.026
Switzerland	3.822***	-2.422***	1.461(1.56)	0.478(0.48)	1.523
Turkey	5.655*	-3.128*	0.437(0.21)	0.863(0.18)	0.606
United Kingdom	7.017*	-3.347*	1.316(0.38)	0.335(0.20)	9.632
United States	9.862*	-1.767***	6.365(3.21)	-2.163(1.61)	19.696

Standard errors are in parentheses
*,**,*** indicate the test statistic lies above, within, or below the 10% bounds.
The upper bound CV for the F-stat are 4.78, 5.73, and 7.84 for 10%, 5% and 1%
The lower bound CV for the F-stat are 4.04, 4.94, and 6.84 for 10%, 5% and 1%
The upper bound CV for the t-stat are -2.91, -3.22, and -3.82 for 10%, 5% and 1%
The lower bound CV for the t-stat are -2.57, -2.86, and -3.42 for 10%, 5% and 1%

Table 2.6. Elliott-Müller Stability Test

	OLS	VEC			ARDL		
Country	$\widehat{qLL}$	$\widehat{qLL}$	CV 5%	CV 10%	$\widehat{qLL}$	CV 5%	CV 10%
Australia	-4.30(0)	-43.47(1)	-35.7	-33.4	-9.06(0)	-14.3	-12.8
Austria	-3.71(1)	-75.19(1)	-35.7	-33.4	-33.18(1)	-30.6	-28.5
Belgium	-4.31(1)	-57.44(1)	-19.8	-18.0	-10.20(0)	-14.3	-12.8
Canada	-2.39(1)	-16.66(0)	-19.8	-18.0	-27.53(1)	-35.7	-33.4
Denmark	-1.71(1)	-23.35(1)	-30.6	-28.5	-19.78(1)	-25.2	-23.3
Finland	-2.58(1)	-27.10(1)	-19.8	-18.0	-34.47(1)	-35.7	-33.4
France	-4.18(1)	-17.07(0)	-19.8	-18.0	-12.02(0)	-14.3	-12.8
Germany	-0.17(1)	-119.61(1)	-40.8	-38.4	-43.96(1)	-35.7	-33.4
Greece	-3.03(1)	-16.15(0)	-19.8	-18.0	-17.93(0)	-14.3	-12.8
Iceland	-3.94(1)	-41.66(1)	-40.8	-38.4	-16.16(0)	-19.8	-18.0
Ireland	-0.46(1)	-16.73(1)	-19.8	-18.0	-6.07(1)	-14.3	-12.8
Italy	-3.72(1)	-19.74(1)	-19.8	-18.0	-28.61(1)	-30.6	-28.5
Japan	-3.30(1)	-35.36(1)	-35.7	-33.4	-15.14(1)	-19.8	-18.0
Luxembourg	-5.04(1)	-82.70(1)	-35.7	-33.4	-30.59(1)	-30.6	-28.5
Netherlands	-5.40(1)	-18.42(1)	-19.8	-18.0	-9.86(1)	-14.3	-12.8
Norway	-2.15(1)	-18.44(1)	-19.8	-18.0	-28.56(1)	-35.7	-33.4
New Zealand	-5.95(1)	-18.14(0)	-19.8	-18.0	-9.19(0)	-14.3	-12.8
Portugal	-2.93(1)	-18.90(1)	-25.2	-23.3	-12.00(1)	-19.8	-18.0
Spain	-1.53(1)	-21.65(1)	-25.2	-23.3	-15.03(0)	-19.8	-18.0
Sweden	-0.18(1)	-22.65(1)	-30.6	-28.5	-23.92(1)	-30.6	-28.5
Switzerland	-2.06(1)	-21.11(0)	-25.2	-23.3	-15.61(1)	-19.8	-18.0
Turkey	-6.53(0)	-16.83(0)	-19.8	-18.0	-9.39(0)	-14.3	-12.8
United Kingdom	-2.28(1)	-40.42(1)	-35.7	-33.4	-31.54(1)	-30.6	-28.5
United States	-0.02(1)	-35.59(1)	-35.7	-33.4	-10.66(1)	-19.8	-18.0

Lags are selected according to BIC criterion and are reported in parentheses.
For the simple OLS model CV's are -8.36 and -7.14 for 5% and 10% levels.

Table 2.7. Degree of Capital Mobility - Review

Country	*OLS*	*VEC*[a]	*ARDL*[a]
Australia	Intermediate (Constant)	High	Intermediate
Austria	Low (Increasing)	High	Low
Belgium	Low (Increasing)	Low	Intermediate
Canada	Intermediate (Increasing)	High	Intermediate
Denmark	Intermediate (Increasing)	High	High
Finland	Low (Increasing)	High	Intermediate
France	Low (Increasing)	Low	Low
Germany	Low (Increasing)	High	High
Greece	Low (Decreasing)	High	High
Iceland	Low (Increasing)	Intermediate	Low
Ireland	High (Increasing)	High	High
Italy	Low (Increasing)	Low	High
Japan	Low (Constant)	Low	High
Luxembourg	High (Increasing)	High	High
New Zealand	Intermediate (Increasing)	High	High
Netherlands	Low (Increasing)	High	High
Norway	High (Increasing)	High	High
Portugal	Intermediate (Decreasing)	Intermediate	Intermediate
Spain	Low (Constant)	Low	Low
Sweden	Intermediate (Increasing)	High	High
Switzerland	Low (Constant)	High	Low
Turkey	Low (Decreasing)	Low	Low
United Kingdom	Intermediate (Constant)	Intermediate	Intermediate
United States	Intermediate (Decreasing)	High	High

The OLS results are a summary of the previous three regressions
[a], VEC and ARDL models are based on the three cases

CHAPTER III

INTEGRATION ANALYSIS OF SAVING AND INVESTMENT RATES

Introduction

The previous chapter provided an in depth review for three key equations used to model the saving-investment relationship. It was shown these models can be used to measure the capital mobility and current account solvency constraint under specific conditions. The most common case for capital mobility was the failure to reject a non-cointegrated relationship. In this chapter I study the integration properties for savings and investment rates. I show both variables are characterized as I(0) variables with a level shift. This result is consistent with parameter instability results reported in the previous chapter and would help explain the inconsistent cointegration results across models.

Throughout the previous chapter the results consistently provide evidence confirming the high correlation between saving and investment rates. The high correlation has remained consistent through time despite using an updated data set and a mix of models. This is in stark contrast to the observation of capital markets becoming increasingly more open into the 21st century. At this point I can conclude one of the following: saving and investment regressions are poor measures of capital mobility, capital markets are not open as many suspect, or despite the best efforts to model the relationship a number of important steps have been omitted. Instead of ending with the first two observations it is important to explore other possible explanations for the high correlation among saving-investment regressions. One potential problem that emerged during estimating the previous models was the inability to accurately model savings and investment rates. A number of exogenous events have occurred over the last fifty year and these events could cause researchers to misinterpret the results. The stability tests provide evidence the dynamic regressions could be suspect to time varying parameters or structural breaks. To better understand the long-run relationship it is of interest to test the integration properties of both variables. Obstfeld and Rogoff (2000) put it best, "The problem is that none of the explanations advanced to date has been terribly convincing. Most explanations tend to be clever but empirically inadequate and, more troublesome still, tend to fix one puzzle at the expense of creating others." The objective of this chapter is to explore the parameter instability results by first testing the integration properties of saving and investment rates followed by tests incorporating structural breaks. Both variables are found stationary or stationary with a break which will most likely bias previous estimates.

Although it was not necessary to test the integration properties of saving and investment rates prior to estimating the previous models, it is common practice. In general the literature has relied upon inferences from traditional unit root tests, i.e.

augmented Dickey-Fuller, Phillips-Perron, and Kwaitkowski et al. (1992). Savings and investment rates fail to reject the non-stationary hypothesis. One extension of this chapter is the use of more powerful unit root tests following Elliott, Rothenberg, and Stock (1996). The stationary results are relatively consistent across tests. One potential concern is the well documented fact that unit root tests are biased toward non-stationarity if the researcher fails to control for significant structural breaks in the data. Finally, allowing for a mean shift greatly increases the likelihood of finding stationary saving-investment rates. In fact, for most countries, savings and investment rates can be considered a stationary series with a level shift.

The remainder of this chapter proceeds as follows. Section 2 provides a brief review of the literature, and more importantly provides arguments against the non-stationary hypothesis for savings and investment rates. Section 3 reviews the unit root tests used to the savings and investment rates and presents the results for each test. Section 4 provides the motivation for testing saving and investment rates for structural breaks, outlines the structural break methodology following the single mean shift models of Perron and Vogelsang (1992) and double mean shift extension by Clemente et al, (1998), and presents the results. Finally, Section 5 lists possible extensions and concludes.

Stationarity

Testing the integration properties of saving and investment rates has become a precursor to using cointegration tests to detect a long-run relationship. Most authors conclude saving and investment rates are non-stationary, but I find these results are sensitive to the unit root tests employed and the failure to model significant breaks in the data. Despite the large number of papers addressing the high correlation the use of newer unit root tests and structural break tests have been ignored. Ozman and Parmaksiz (2003a and 2003b) and Kejriwa (2008) have questioned the stability of the cointegrating relationship and test for structural breaks in the residuals from saving-investment regressions. Instead of testing the cointegrating properties, the goal of this chapter is to take a step back and examine the stationary properties for saving and investment rates prior to testing for a cointegrating relationship. This chapter presents results that find, through the use of more powerful unit root tests and controlling for mean breaks, that saving and investment rates are more likely to be stationary with a level shift.

In addition to being useful for measuring capital mobility, unit root tests for saving and investment rates can be used to measure other key results in the macroeconomics literature. One example is the important result stemming from real business cycles model that claim real macroeconomic variables share a common stochastic trend in productivity. King, Plosser, and Rebelo (1988) predict that per capita consumption, investment, and output all grow at the same rate in steady state. Essentially each series is stationary which implies consumption to output and investment to output ratios are also stationary. These ratios are commonly referred to as the great ratios. Given the relationship between consumption, investment, and saving it is easy to see saving rates will also be stationary. In a closed economy neoclassical model the solutions for each variable can easily be derived, $I/Y = S/Y$ and $C/Y = (1 - S/Y)$, where C, I, S, and Y denote consumption, investment, saving, and output. The logic for the open economy model is also straight forward after accounting for net capital outflows. The inclusion of net capital outflows should not alter the stationary properties for either variable; net capital outflows are stationary because countries face a long-run budget constraint.

By definition a non-stationary series will be non-mean reverting with a variance that approaches infinity. Despite a number of papers finding saving and investment rates I(1), the non-stationary definition does not fit either series. First, saving and investment rates are calculated as residuals from national accounting identities. Second both variables are bound by zero and one. Third, the growth and consumption smoothing theory literatures provide evidence against the non-stationary hypothesis. Since both variables are expressed relative to gross domestic product the specific time paths are difficult to deduce. Resorting to economic theory both neoclassical and real business cycle models suggest saving and investment rates are stationary.

Figures 1.1 and 1.2 show saving and investment rates from 1950-2004 for OECD countries. In the figures it can be seen the data are relatively noisy, exhibit structural change, and for most countries saving and investment rates move together over time. Saving and investments rates are bound between 0 and 1. Looking at data for OECD countries from 1950-2004 the minimum saving and investment rates are -0.016 and 0.055 and the maximum values are 0.493 and 0.434, respectively. Testing saving and investment rates using short data sets could bias the results toward non-stationarity and thus the variables could appear cointegrated. Kejriwal (2008) argues the 0-1 bound on saving and investment rates are not constraining, and it is appropriate to model a persistent series as I(1) processes rather than I(0).

A number of authors have tested saving and investment rates for unit roots and conclude both saving and investment rates are non-stationary. Taken at face value non-stationarity implies shocks to saving and investment will cause the variables to permanently deviate from their steady state value. According to neoclassical growth theory this will cause a permanent change in long-run growth rates. More reasonably one would suspect shocks to investment and saving rates to be transitory; both variables will temporarily deviate from their steady state values. At a minimum, a permanently higher saving rate will increase growth rates above steady state levels, but will not change the steady state. Over time growth rates will converge back to the steady state level. During this adjustment process investment will gradually increase to higher levels. Over time both saving and investment rates increase, but this does not necessarily imply saving and investment rates are non-stationary. The non-stationary results are more likely caused by the failure to appropriately model saving and investment rates. The first step is to test saving and investment rates using traditional and more powerful unit root tests.

Unit Root Tests

Traditional Tests

Saving and investment rates are first tested for non-stationarity using augmented Dickey-Fuller (ADF), Phillips-Perron, and KPSS unit root tests. These tests provide a starting point for the analysis but come with their own set of problems. It is well documented the augmented Dickey-Fuller and Phillips-Perron tests have low power in small sample sizes and the KPSS tends to over-reject the stationary null hypothesis. Given these shortcomings it will not be surprising to find both variables fail to reject the non-stationary hypothesis. In general the KPSS is used for confirmatory analysis.

The inclusion of a trend term is often a point of debate; Taylor (2002) tests saving and investment rates for stationarity, via an ADF regression, excluding a trend term. A number of authors include a trend term only when it is significant. There are a number of different statistical qualifications when it comes to the inclusion of a trend term. Generally the trend term is included when it is significant or if a trend improves the regression according to information criteria. In addition to using the statistical tests for inclusion of a trend, resorting to economic theory is helpful. Whether or not saving and investment rates are trend or level stationary has different implications. Both variables are expressed relative to gross domestic product which makes it difficult to justify the inclusion of a trend term. Saving and investment rates will eventually converge to a constant level in the long-run. A trend will only be significant during the adjustment to the long-run equilibrium. This logic suggests both variables should be level stationary. For this reason Taylor does not include a trend. With shorter data sets the inclusion of a trend term might bias the results toward stationarity as the trend term may serve as a proxy for mean shifts.

The starting point for the ADF test begins with estimating the following equation:

$$\Delta y_t = \alpha_0 + \alpha_1 t + \rho y_{t-1} + \sum_{i=1}^{k} \beta_i \Delta y_{t-i} + \varepsilon_t \qquad \text{(III.1)}$$

where t is a trend term, the lag lengths, k, are selected according to the Akaike information criteria (AIC) statistic from Akaike (1973).[1] Lag difference terms are included to control for serial correlation. The series is said to be stationary for values of ρ statistically different from zero. The Phillips-Perron test differs from the ADF test as it ignores serial correlation in the initial test equation, but uses a nonparametric approach that modifies the tests statistics to control for serial

[1] Although the results are not reported here, using Schwarz information criteria (SIC) (Schwarz, 1978) and sequential t-tests (Ng-Perron, 1995), do not alter any of the conclusions reached in this chapter.

correlation and heteroscedasticity. The Phillips-Perron and ADF tests have the same asymptotic distribution. Since both the Phillips-Perron and ADF tests use non-stationarity as the null hypothesis it is useful to include a stationarity test for confirmatory analysis. The most common test involving a stationary hypothesis is presented by Kwiatkowski, Phillips, Schmidt and Shin (1992). The KPSS test is performed using the lag selected according to the automatic bandwidth selection procedure proposed by Newey and West (1994) and the residual variance of NeweyWest estimator.

These test results will mostly likely produce false inferences. ADF and Phillips-Perron tests have been shown to have low power and severe size distortions when Δy_t has an ARMA representation with a large negative MA component. This distortion would result in over-rejection of the non-stationary null hypothesis. Additionally, both tests have low power against stationary alternatives when the roots are near unity. These tests will fail to distinguish persistent stationary processes from non-stationary processes. One reason for excluding a trend term is because both tests lose power when deterministic terms are added to the test regressions. Clearly making inferences based solely on ADF, Phillips-Perron, and KPSS tests could lead to false conclusions. The next section will review the improved unit root tests following Elliott, Rotherberg, and Stock (1996).

More Powerful Tests

Although there have been a number of improvements in the size and power of unit root tests within the saving-investment literature, most researchers have ignored the newer tests in favor of using recently developed panel unit root tests. Panel unit root tests avoid the power problem associated with traditional unit root tests, but come with additional concerns. The null hypothesis is not well defined and the reported t-statistics are a weighted average of the traditional Dickey-Fuller unit root tests for a single time series. The weight average approach leaves the possibility of modeling the variables as I(1) even when a large portion of countries have stationary components. Panel unit root tests provide very little intuition behind movements in saving and investment rates, and the tests ignore heterogeneity between countries. Nevertheless, these shortcomings have been ignored and a number of recent papers have employed panel unit root tests. Instead of panel unit root tests, saving and investment rates are tested using a more powerful test following Elliott, Rothenberg, and Stock (1996). Elliott, Rothenberg, and Stock (1996) (ERS henceforth) propose a generalized least squares test along the lines of an augmented Dickey-Fuller test.

The series is transformed via a generalized least squares regression before performing an ADF test on the quasi-difference series. The Dickey-Fuller generalize least squares (DF-GLS) test has been shown to have significantly more power than traditional ADF tests. Before testing the series via an ADF regression the DF-GLS test applies generalized least squares to detrend (demean) series y_t. Next the residuals from the previous step are used to construct an augmented Dickey-Fuller regression. The residuals are calculated as:

$$y_t^d = y_t - \hat{\beta}' z_t. \tag{III.2}$$

For the detrending case $z_t = (1, t)'$ and $\hat{\beta}_0$ and $\hat{\beta}_1$ are calculated by regressing $[y_1, (1 - \bar{\alpha} L y_2), ..., (1 - \bar{\alpha} L y_T)]$ onto $[z_1, (1 - \bar{\alpha} L z_2), ..., (1 - \bar{\alpha} L z_T)]$ where $\bar{\alpha} = 1 + \bar{c}/T$ with $\bar{c} = -13.5$ and L is the lag operator. For demeaning, $z_t = (1)'$ and $\bar{c} = -7.0$. The quasi-difference series, constant, and trend terms are sensitive to the value of $\bar{c}$. ERS show fixing $\bar{c}$ equal to -7 in the model with a drift and -13.5 in the linear trend case achieve maximum power.

Data and Results

Results for the OECD countries are presented in tables 3.1 and 3.2. Augmented Dickey-Fuller tests reject non-stationary at the 5% level for Australia, Belgium, New Zealand, Switzerland, and United States. France, Germany, Norway, and United Kingdom reject non-stationarity at the 5% in only one test. The use of the KPSS test confirms stationarity for Belgium, France, Germany, Norway, and United Kingdom, but also suggests saving rates could exhibit fractional integration for Australia, New Zealand, and Switzerland, joint acceptance or rejection of the null hypothesis for the ADF/PP and KPSS tests. In the end, nine countries exhibit level stationary saving rates. Results from the DF-GLS test are presented in table 3.2. These results confirm stationarity for Australia, France, New Zealand, Norway, and United States. Additionally the more powerful unit root tests reject non-stationarity for Finland, Norway, Portugal, and Turkey. For comparison the DF-GLS is also estimated via the detrending procedure. Canada can reject non-stationary at the 5% level in favor of the alternative hypothesis of trend stationary.

The results are similar for investment rates. Australia, Austria, Belgium, Canada, Luxembourg, and Portugal are found to reject non-stationarity at the 5% level for both ADF and Phillips-Perron unit root tests. New Zealand, Switzerland, and United Kingdom reject non-stationarity in either the ADF or Phillips Perron test. The KPSS test confirms stationarity for Canada, Switzerland, and United Kingdom. Investment rates might be fractional integrated for a large set of countries including: Australia, Austria, Luxembourg, and New Zealand. The DF-GLS test confirms stationarity for Australia, Austria, Canada, Luxembourg, and Portugal. The tests also reject non-stationarity for Denmark, Ireland, and United States. New Zealand and Turkey reject non-stationary in favor of trend stationarity.

Jointly saving and investment rates reject non-stationary for Australia, Belgium, Portugal, Turkey, and United States. A number of other countries fall into uncertain category, these include: Austria, Switzerland, and United Kingdom. The joint rejection of non-stationarity has important implications. First it can be seen as a measure of increased capital mobility. If both variables are I(0) then cointegration tests are inappropriate. Further this confirms the basic argument from real business cycle models, countries in the steady state will have stationary investment and saving ratios.

As expected traditional and more powerful unit root tests were not able to reject non-stationarity for a large number of countries. This suggests a couple of possible extensions. One extension is to assume the variables are non-stationary and test for a cointegrating relationship. The second approach is to further analyze each variable for potential abnormalities. It is well documented that unit root tests have lower power of rejecting the null hypothesis when a structural shift is present. The saving-investment literature has gone the route of the first extension. This has lead to a number of contradicting results. Research has been unable to adequately determine if saving and investment rates are cointegrated, the results are sensitive to the data set and cointegration methods employed. This motivates my use of the second approach. Instead of proceeding into more elaborate cointegration modeling I elect to test both variables for level shifts. The existence of structural shifts will bias the unit root tests and could also lead to incorrect or bias inferences in cointegration results.

Structural Breaks

One possible explanation behind a large number of countries having saving and investment rates that fail to reject unit roots is the presence of structural breaks.

Visually inspecting graphs for saving and investment rates suggests both variables could have structural breaks. There are a number of time periods to expect a shift in either variable. The most notable events are the breakdown of the Bretton Woods system, the oil crisis in 1973 and 1979, a global recession beginning in the early 1970's and 1980's, and the East Asian Miracle and subsequential financial crises. There is a large literature explaining how to model structural breaks when testing for unit roots. For the purpose of this section structural breaks are tested using an endogenous single mean shift from Perron and Vogelsang (1992). When a series displays evidence of a unit root under the single mean shift model the double mean shift model proposed by Clemente et al. (1999) is estimated.

There are a number of variables that can cause saving and investment rates to shift. In a basic Solow growth model a permanent change in the saving rate will cause growth rates to temporarily deviate from their steady state and investment rates to gradually increase to a higher level in the long-run. The idea of consumption smoothing implies negative shocks to consumption will result in lower saving rates as household attempt to maintain constant levels of consumption. The difficulty arises determining if the breaks are permanent, transitory, gradual, or sudden. Using data for France and United Kingdom, Ozman and Parmaksiz (2003a and 2003b) test saving and investment rates for a single endogenous mean shift. They test for a single shift in the cointegrating relationship between both variables and find evidence of a shift following the breakdown of the Bretton Woods system.

Ozman and Parmaksiz and Kejriwal (2008) are the only authors to test for structural breaks in the cointegrating relationship.

Instead of focusing on the cointegration relationship between saving and investment rates I argue the cointegration result stems from the failure to accurately control for structural breaks in the independent series. The existence of structural breaks will cause a spurious correlation between saving and investment rates if the breaks are independent events. In the context of capital mobility this will lead to false inferences in the Feldstein-Horioka regressions; incorrectly inferring imperfect capital immobility when saving-investment regressions yield a large savings coefficient. Further, failing to control for exogenous structural breaks will result in non-stationary saving and investment rates. This is in contradiction to the basic premise of real business cycle models. A more appropriate view is the following: if the economy is operating at the steady state, saving and investment rates will be stationary. Suppose an negative exogenous shock occurs, i.e. the oil price shock of 1973 and 1979, the economy will sudden move away from the steady state. The shock will cause income, saving, investment, and consumption to shift. Given the shock is temporary the variables will gradually return to the previous steady state levels. Saving and investment rates do not display evidence of non-stationary, but the failure to control for structural breaks will falsely accept the non-stationary hypothesis. I show for most countries, saving and investment rates are suspectable to structural breaks.

Methodology

This section extends the saving-investment literature by applying structural break tests to both variables. It is commonly known that one reason unit root tests fail to reject non-stationarity is due to the presence of structural breaks. Testing the Nelson-Plosser data for structural breaks, Perron (1989) shows most macroeconomic variables are trend stationary with a significant mean shift. Perron and Vogelsang (1992) develop a unit root test statistic that allows for a permanent level shift in a series which is used throughout this section. Perron and Vogelsang develop two classes of models: first is the 'additive outlier' (AO) model which captures sudden shifts in a series and second is the 'innovative outlier' (IO) model which models a gradual adjustment. Neither model requires a priori knowledge of the break points. Break points are selected by searching over all possible year combinations and selecting the break date that minimize the pseudo t-ratio in an augmented Dickey-Fuller (ADF) regression.

Clemente et al. (1998) extend the single break point model to capture double mean changes. The null hypothesis under the double change model is:

$$H_0 : y_t = y_{t-1} + \delta_1 DTB_{1t} + \delta_2 DTB_{2t} + u_t \quad \text{(III.3)}$$

against the alternative hypothesis:

$$H_a : y_t = \mu + d_1 DU_{1t} + d_2 DTB_{2t} + u_t. \quad \text{(III.4)}$$

DTB_{it} is a pulse variable that takes the value of 1 if $t = TB_i + 1 (i = 1, 2)$ and 0 otherwise; $DU_{it} = 1$ if $t > TB_i (i = 1, 2)$ and 0 otherwise. TB_1 and TB_2 are the time periods when the mean shift occurs. This methodology is equivalent to the single mean shift model of Perron and Vogelsang if $d_2 = 0$.

The double break point IO model consists of estimating the following model:

$$y_t = \mu + \rho y_{t-1} + \delta_1 DTB_{1t} + \delta_2 DTB_{2t} + d_1 DU_{1t} + d_2 DU_{2t} + \sum_{i=1}^{k} c_i \Delta y_{t-1} e_t. \quad \text{(III.5)}$$

The minimum value of the pseudo t-ratio is found by testing whether the autoregressive parameter is 1 for all break time combinations. Clemente et al. report the critical values which are used in tables 3.3 and 3.4.

Shifts in saving and investment rates could also be characterized by additive outliers. Testing the null hypothesis of a unit root with additive outliers is a two-step process. First the deterministic part of the variable is removed by estimating the following model:

$$y_t = \mu + d_1 DU_{1t} + d_2 DU_{2t} + \tilde{y}_t \quad \text{(III.6)}$$

where the residuals, $\tilde{y}_t$, are regressed on their lagged values, lagged differences, and a set of dummy variables capturing the additive shifts. The second step entails estimating the following model:

$$y_t = \sum_{i=0}^{k} \omega_{1i} DTB_{1t-i} + \sum_{i=0}^{k} \omega_{2i} DTB_{2t-i} + \rho \tilde{y}_{t-1} + \sum_{i=1}^{k} c_i \Delta \tilde{y}_{t-1} + e_t, \quad \text{(III.7)}$$

which again yields a test of ρ statistically different from one in the case of stationarity. Using data covering 1950-2004 the AO and IO models captures shifts in investment and saving rates that might otherwise be identified as departures from stationarity.

Results

The results for the structural break tests are presented below. The innovative outlier test results are presented in tables 3.3 and 3.4 and additive outlier test results are reported in tables 3.5 and 3.6. The tables present the results for the AR(1) coefficient, unit root test statistic, optimal break date and coefficient measuring the magnitude of the break date, number of lags included, and the level of significance. In order to be parsimonious the single shift model of Perron and Vogelsang is estimated and if the null hypothesis fails to be rejected then the double mean shift model of Clemente et al. is conducted.

Innovative Outlier Tests

The innovative outlier tests allow for a gradual change over time. These tests are appropriate for a large sample of macroeconomic time series variables. For example, in the event of an increase in the steady state level of output investment and consumption with increase to higher levels at an increasing rate. Eventually these variables will settle into a new steady state level. In the context of unit root testing the innovative outlier approach will test if the variables are level stationary controlling for the adjustment period. Table 3.3 and 3.4 present the results for investment and saving rates.

Investment rates are considered level stationary with a mean break for 13 countries. In addition to the previously estimated unit root tests Finland, Iceland, and Netherlands reject non-stationarity with an alternative of level stationary with a mean shift. Saving rates reject non-stationary for 17 countries. In addition to the previous section the non-stationary hypothesis is rejected for Austria, Iceland, Ireland, Italy, and Netherlands. The double mean shift is estimated when the single mean shift model fails to reject non-stationarity. Denmark, Finland, and Iceland display evidence of investment rates having two mean shifts. Belgium, Ireland, and Italy display evidence of saving rates having two mean shifts.

Both tables also present the optimal break dates for rejecting non-stationary. These break dates correspond to dates in conjunction with minimizing t_ρ and do not necessarily correspond to optimal break dates for the individual series. Since I am concerned with the integration properties, when a variable is found stationary the process will completely ignoring the significance of the structural breaks. An additional number of break points could be significant. The double mean results are only reported when they provided useful for determining the integration properties, when they reject non-stationarity at a higher level of significance then the single break model. Nevertheless, countries appear to have common break dates surrounding the break down of Bretton Woods and the 1973-1975 recession and the oil crisis in 1979 through 1981. Other notably time periods associated with a break include the late 1950's as countries recovered from World War II and the 1990's from the investment boom.

Additive Outlier Tests

In addition to testing for gradual adjustment, each variable is tested for an additive outlier effect. This approach tests for unit roots controlling for sudden shifts. Again this approach is relevant for both variables. A sudden shift to saving and investment rates is likely to result from policy changes, cost shocks, or current account reversals. Tables 3.5 and 3.6 present the additive outlier model for investment and savings rates. Under the additive outlier model Italy, New Zealand, Norway, Spain, and United Kingdom join the group of countries rejecting the non-stationary hypothesis for investment rates. Likewise, saving rates reject non-stationary for Canada, Germany, and Spain. The break dates reported from the additive outlier tests correspond to the previous breaks found under the innovative outlier tests.

Given the large number of unit root tests conducted in sections 3 and 4 it is helpful to summarize the results. Table 3.7 compactly summarizes the previous results. The table highlights countries that have stationary saving and investment rates and also presents the level of rejection for the structural break tests. Austria, Denmark, Greece, Japan, Luxembourg, and Sweden are the only countries that fail to reject non-stationarity for saving rates. Investment rates are non-stationary for France, Germany, Greece, Japan, and Sweden. There are a couple of important conclusions that can be reached. Given the overwhelming results in favor of stationarity only Greece, Japan, and Sweden have non-stationary saving and investment rates. One cannot help but question the widespread conclusion of a cointegrated relationship between saving and investment rates. Determining the integration properties for both variables are likely to be influenced by exogenous breaks. These breaks can result from the move to floating exchange rates, global business cycles, or country specific effects.

Conclusion

In this chapter I analyze the integration properties of saving and investment rates for a group of OECD countries. The motivation for this chapter comes from the belief that saving and investment rates, when expressed relative to income, are suspectable to a number of significant exogenous shocks. Failure to control for these shocks will bias the unit root tests against rejecting non-stationarity. This is consistent with the findings in the literature. I suspect one possible reason concluding both variables follow a non-stationary process is that failure to account for structural change. First I compare the results from traditional unit root tests to the Dickey Fuller GLS test, a more powerful test proposed by Elliott, Rothemberg, and Stock (1996). The Dickey-Fuller GLS unit root test is most likely to reject non-stationarity relative to the augmented-Dickey Fuller and Phillips-Perron tests. The Dickey-Fuller GLS test is only a marginal improvement in my objective of finding both variables level stationary. When looking across all three tests, Phillips-Perron, augmented Dickey-Fuller, and Dickey Fuller GLS, at least one test rejects non-stationarity in favor of an alternative that investment and saving rates are level or trend stationary for 9 and 12 countries, respectively. These results are promising but need to be interpreted with caution. Despite the improvement in the power of the Dickey Filler GLS test the failure to account for structural breaks in the data will bias the results toward non-stationarity.

The next step involves testing the integration properties controlling for structural breaks using the single and double mean shift model proposed by Perron and Vogelsang (1992) and Clemente et al., (1998). After controlling for structural breaks in the mean 21 countries are found to have saving and investment rates reject non-stationary in favor of level stationary with a break. This provides some guidance after concluding the saving-investment relationship when modeled through linear regression models are unstable. After documenting saving and investment rates are more likely characterized by a stationary process, the question becomes how should one model the joint relationship. The error correction model is still an appropriate selection to capture short and long-run dynamics, but the instability found in the last chapter and the structural break evidence presented here need to be controlled. Because the stationary results are conditional on the inclusion of a structural break when modeling the joint relationship it is important to control for the exogenous shocks. The next chapter will optimally test for structural breaks, demean both variables, and apply the results to the saving-investment regressions.

Table 3.1. Augmented Dickey-Fuller, Phillips-Perron, and KPSS

		Saving Rates				Investment Rates			
Country	N	ADF	PP	KPSS	Lags	ADF	PP	KPSS	Lags
Australia	55	-3.963***	-4.160***	1.342***	0	-5.173***	-5.223***	0.480**	0
Austria	55	-2.821*	-2.738*	1.023***	0	-3.298**	-3.164**	0.652**	0
Belgium	55	-3.025**	-3.064**	0.403*	0	-2.630*	-2.572	1.772***	0
Canada	55	-1.995	-1.389	1.377***	1	-4.230***	-4.207***	0.165	0
Denmark	55	-2.181	-1.484	1.241***	1	-2.415	-2.366	0.731**	0
Finland	55	-2.476	-2.429	2.818***	0	-0.760	-1.197	1.265***	2
France	55	-3.304**	-1.933	0.136	6	-2.081	-2.068	0.878***	0
Germany	35	-2.054	-3.324**	0.430*	6	-0.381	-1.506	0.790***	4
Greece	54	-1.460	-1.436	1.994***	0	-1.512	-1.538	1.179***	0
Iceland	55	-0.666	-1.797	0.930***	3	-0.635	-2.613	0.627**	6
Ireland	55	-0.564	-0.299	4.872***	0	-2.373	-2.285	1.006***	0
Italy	55	-1.314	-1.239	1.734***	1	-1.130	-1.123	4.114***	0
Japan	55	-1.262	-2.189	1.299***	1	-1.537	-2.427	1.151***	1
Luxembourg	55	-1.763	-1.497	1.178***	0	-3.133**	-3.142**	2.579***	0
Netherlands	55	-2.748	-2.728*	1.180***	0	-0.569	-1.834	1.363***	2
New Zealand	55	-5.138***	-5.191***	0.839***	0	-2.491	-4.183***	0.486**	6
Norway	55	-2.564	-3.350**	0.147	2	-1.346	-1.241	3.744***	0
Portugal	55	-2.590	-2.840*	0.082	7	-3.856***	-3.044**	0.673**	1
Spain	55	-2.632	-2.536	1.093***	0	-2.671*	-2.380	0.414*	1
Sweden	55	-2.098	-2.436	0.364*	1	-1.066	-1.464	0.725**	5
Switzerland	55	-3.099**	-4.416***	0.830***	1	-2.728*	-3.113**	0.349*	1
Turkey	55	-2.512	-2.511	2.334***	0	-2.420	-2.329	2.843***	0
United Kingdom	55	-2.962**	-2.889*	0.461*	1	-2.403	-3.775***	0.226	5
United States	55	-4.735***	-3.884***	0.426*	1	-2.783*	-2.819*	1.724***	0

*,**,*** indicate 10%, 5% and 1% significance.
Critical values for ADF and PP are -3.628, -2.950, and -2.608 for 1%, 5%, and 10%
Critical values for KPSS are 0.739, 0.463, and 0.347 for 1%, 5%, and 10%
Bartlett kernel and Newey-West Bandwidth are used for the PP tests
Lag length selected according to Akaike (1973) information criterion

Table 3.2. Dickey-Fuller Generalized Least Squares

		Saving Rates				Investment Rates			
Country	N	DF-GLS	Lags	Trend	Lags	DF-GLS	Lags	Trend	Lags
Australia	55	-2.424**	0	-3.625**	0	-5.217***	0	-5.204***	0
Austria	55	-1.238	0	-2.273	0	-1.818*	2	-1.868	2
Belgium	55	-1.331	10	-2.198	0	-2.656***	0	-3.031*	0
Canada	55	-0.937	2	-3.490**	1	-4.208***	0	-4.051***	2
Denmark	55	-0.370	2	-1.689	2	-2.413**	0	-2.429	0
Finland	55	-2.079**	0	-2.843	0	-0.985	2	-1.431	2
France	55	-1.740*	0	-1.803	0	-1.847*	0	-1.985	0
Germany	35	-0.789	6	-1.804	0	1.019	4	-2.433	2
Greece	54	-1.296	0	-1.512	0	-1.348	0	-1.459	0
Iceland	55	-0.783	3	-1.189	3	-0.786	6	-0.988	6
Ireland	55	0.748	0	-2.684	0	-2.051**	0	-2.369	0
Italy	55	-1.553	2	-1.798	1	-1.166	0	-2.064	0
Japan	55	-0.569	1	-0.875	1	-0.659	1	-0.877	1
Luxembourg	55	-1.726*	0	-1.726	0	-1.670*	0	-3.473**	0
New Zealand	55	-2.132**	0	-3.462**	0	-1.083	6	-3.663**	5
Netherlands	55	-1.161	2	-1.566	2	-1.429	0	-2.995*	0
Norway	55	-2.172**	2	-2.426	2	-1.143	0	-2.796	0
Portugal	55	-3.368***	1	-1.870	4	-2.793***	1	-4.003***	1
Spain	55	-0.894	4	-1.518	4	-1.405	1	-2.064	2
Sweden	55	-1.929*	0	-2.240	0	-1.609	10	-1.666	10
Switzerland	55	-0.899	0	-1.922	0	-1.734*	1	-2.241	1
Turkey	55	-2.104**	0	-4.170***	2	-1.764*	0	-4.321***	2
United Kingdom	55	-1.127	0	-1.512	0	-0.450	5	-1.563	2
United States	55	-2.321**	1	-3.752**	1	-2.352**	0	-3.342**	1

*,**,*** indicate 10%, 5% and 1% significance.
Critical values for DF-GLS are -2.630, -1.950, and -1.608 for 1%, 5%, and 10%
Critical values for DF-GLS with trend are -3.770, -3.190, and -2.890 for 1%, 5%, and 10%
Lag length selected according to Akaike (1973) information criterion

Table 3.3. Innovative Outlier Model, Investment Rates

Country	ρ	t_ρ	K	TB_1	δ_1	TB_2	δ_2	Level
Australia	-0.794	-5.692	0	1972	-1.423			1
Austria	-0.457	-3.918	0	1958	1.598			10
Belgium	-0.830	-5.378	5	1979	-2.937			1
Canada	-0.593	-4.544	0	1988	0.036			5
Denmark	-0.662	-6.179	0	1957	5.085	1978	-3.474	1
Finland	-0.590	-6.340	0	1974	-2.308	1989	-5.948	1
France	-0.172	-2.375	0	1979	-0.416			
Germany	-0.206	-2.272	2	1991	-1.184			
Greece	-0.129	-2.422	0	1972	-1.749			
Iceland	-0.797	-6.177	0	1974	-2.819	1981	-4.605	5
Ireland	-0.267	-3.107	0	1957	1.880			
Italy	-0.230	-2.821	6	1973	-1.873			
Japan	-0.200	-3.283	1	1957	2.599			
Luxembourg	-0.709	-5.659	0	1965	-5.950			1
Netherlands	-0.425	-3.865	0	1979	-3.030			10
New Zealand	-0.817	-3.022	6	1973	-1.140			
Norway	-0.401	-1.841	8	1987	-4.523			
Portugal	-0.640	-5.282	1	1958	3.774			1
Spain	-0.187	-2.916	1	1973	-0.369			
Sweden	-0.363	-3.078	5	1975	-1.995			
Switzerland	-0.311	-3.143	1	1973	-1.013			
Turkey	-0.422	-3.832	0	1985	3.103			10
United Kingdom	-0.435	-3.485	1	1958	1.637			
United States	-0.588	-3.735	2	1995	1.721			10

Table 3.4. Innovative Outlier Model, Saving Rates

Country	ρ	t_ρ	K	TB_1	δ_1	TB_2	δ_2	Level
Australia	-0.654	-3.870	6	1972	-2.146			10
Austria	-0.377	-3.842	0	1953	2.322			10
Belgium	-0.512	-5.638	0	1979	-3.069	1986	3.412	5
Canada	-0.284	-2.617	0	1977	1.028			
Denmark	-0.153	-2.596	0	1980	0.763			
Finland	-0.559	-4.952	0	1983	-3.073			1
France	-0.385	-4.644	6	1978	-0.890			5
Germany	-0.305	-2.054	6	1972	0.000			
Greece	-0.245	-2.596	8	1979	-2.550			
Iceland	-0.461	-4.232	1	1980	-3.751			5
Ireland	-0.355	-5.270	1	1980	3.816	1993	4.512	10
Italy	-0.497	-5.458	1	1968	-2.129	1978	-2.292	10
Japan	-0.045	-1.247	1	2000	0.036			
Luxembourg	-0.159	-1.921	4	1995	2.359			
Netherlands	-0.361	-4.538	0	1973	-1.255			5
New Zealand	-0.703	-5.993	0	1958	-1.406			1
Norway	-0.521	-4.549	1	1983	-0.910			5
Portugal	-0.400	-4.526	1	1971	-1.075			5
Spain	-0.179	-2.709	0	1980	-0.073			
Sweden	-0.285	-2.853	0	1974	-0.615			
Switzerland	-0.454	-4.260	4	1957	1.399			5
Turkey	-0.483	-4.208	0	1985	3.002			5
United Kingdom	-0.180	-3.202	0	1984	-0.474			
United States	-0.812	-4.314	5	1980	-0.706			5

Table 3.5. Additive Outlier Model, Investment Rates

Country	ρ	t_ρ	K	TB_1	δ_1	TB_2	δ_2	Level
Australia	-0.793	-5.847	0	1971	-1.723			1
Austria	-0.302	-2.497	6	1977	-0.697			
Belgium	-0.481	-3.615	2	1978	-2.934			5
Canada	-0.563	-4.358	0	1959	-0.788			1
Denmark	-0.234	-2.292	3	1977	-2.507			
Finland	-0.515	-4.706	1	1987	-10.190			1
France	-0.170	-2.340	0	1978	-0.930			
Germany	-0.256	-1.767	4	1994	-5.808			
Greece	-0.200	-1.915	8	1978	-6.739			
Iceland	-0.849	-6.107	0	1973	-1.299	1983	-7.404	5
Ireland	-0.200	-2.463	1	1977	1.566			
Italy	-0.313	-3.486	0	1978	-7.310			10
Japan	-0.140	-0.955	7	1962	10.863			
Luxembourg	-0.625	-5.005	0	1968	-7.719			1
Netherlands	-0.467	-4.003	0	1978	-6.740			5
New Zealand	-0.676	-5.095	1	1972	-1.419			1
Norway	-0.623	-4.638	3	1984	-9.275			1
Portugal	-0.664	-5.262	1	1961	4.949			1
Spain	-0.265	-3.609	1	1957	5.060			5
Sweden	-0.395	-2.426	5	1978	-4.698			
Switzerland	-0.274	-2.987	2	1972	-1.389			10
Turkey	-0.403	-3.650	0	1988	6.676			5
United Kingdom	-0.617	-3.732	6	1961	2.898			5
United States	-0.508	-4.274	0	1995	2.594			1

Table 3.6. Additive Outlier Model, Saving Rates

Country	ρ	t_ρ	K	TB_1	δ_1	TB_2	δ_2	Level
Australia	-0.638	-5.086	0	1971	-2.116			1
Austria	-0.258	-2.386	5	1977	0.392			
Belgium	-0.194	-2.435	1	1979	-0.869			
Canada	-0.554	-4.712	1	1996	4.316			1
Denmark	-0.183	-2.508	0	1991	4.556			
Finland	-0.538	-3.522	3	1987	-4.934			5
France	-0.210	-3.095	3	1977	-1.031			10
Germany	-0.650	-4.529	1	1976	-4.560			1
Greece	-0.193	-2.544	0	1984	-9.099			
Iceland	-0.520	-4.690	0	1982	-6.560			1
Ireland	-0.217	-2.761	0	1991	18.274			
Italy	-0.215	-3.207	1	1976	-5.871			10
Japan	-0.244	-2.683	0	1963	11.764			
Luxembourg	-0.176	-2.283	0	1994	6.817			
Netherlands	-0.359	-4.176	0	1976	-2.525			5
New Zealand	-0.700	-5.740	0	1968	-2.233			1
Norway	-0.499	-4.383	1	1982	-1.227			1
Portugal	-0.176	-1.796	4	1970	-1.905			
Spain	-0.303	-3.279	1	1957	4.419			5
Sweden	-0.244	-1.494	7	1973	-1.903			
Switzerland	-0.486	-4.537	1	1956	5.889			1
Turkey	-0.440	-3.785	0	1984	5.350			5
United Kingdom	-0.179	-3.169	0	1983	-0.752			
United States	-0.660	-5.706	1	1979	-0.954			1

Table 3.7. Unit Root Summary

Country	Saving Rates *ADF/PP/KPSS*[a]	DF-GLS	AO	IO	Investment Rates *ADF/PP/KPSS*[a]	DF-GLS	AO	IO
Australia	**I(0)**	**I(0)**	1%	10%	**I(0)**	**I(0)**	1%	1%
Austria	I(1)	I(1)		10%	**I(0)**	I(1)		10%
Belgium	**I(0)**	I(1)		5%	I(1)	**I(0)**	5%	1%
Canada	I(1)	I(1)	1%		**I(0)**	**I(0)**	1%	5%
Denmark	I(1)	I(1)			I(1)	**I(0)**		1%
Finland	I(1)	**I(0)**	5%	1%	I(1)	I(1)	1%	1%
France	**I(0)**	I(1)	10%	5%	I(1)	I(1)		
Germany	**I(0)**	I(1)	1%		I(1)	I(1)		
Greece	I(1)	I(1)			I(1)	I(1)		
Iceland	I(1)	I(1)	1%	5%	I(1)	I(1)	5%	5%
Ireland	I(1)	I(1)		10%	I(1)	**I(0)**		
Italy	I(1)	I(1)	10%	10%	I(1)	I(1)	10%	
Japan	I(1)	I(1)			I(1)	I(1)		
Luxembourg	I(1)	I(1)			**I(0)**	I(1)	1%	1%
Netherlands	I(1)	I(1)	5%	5%	I(1)	I(1)	5%	10%
New Zealand	**I(0)**	**I(0)**	1%	1%	I(1)	I(1)	1%	
Norway	**I(0)**	**I(0)**	1%	5%	I(1)	I(1)	1%	
Portugal	I(1)	**I(0)**		5%	**I(0)**	**I(0)**	1%	1%
Spain	I(1)	I(1)	5%		I(1)	I(1)	5%	
Sweden	I(1)	I(1)			I(1)	I(1)		
Switzerland	**I(0)**	I(1)	1%	5%	I(1)	I(1)	10%	
Turkey	I(1)	**I(0)**	5%	5%	I(1)	I(1)	5%	10%
United Kingdom	**I(0)**	I(1)			I(1)	I(1)	5%	
United States	**I(0)**	**I(0)**	1%	5%	I(1)	**I(0)**	1%	10%

[a] Stationarity is assumed if the variable is found stationary at the 5% for two tests.

CHAPTER IV

TESTS FOR STRUCTURAL CHANGE

Introduction

The results in the previous section provide overwhelming evidence rejecting non-stationarity for saving and investment rates. For years researchers were under the assumption that both variables were non-stationary and proceeded into cointegration methods to test the long-run relationship and measure capital mobility. Because countries face borrowing constraints eventually savings and investment rates must converge overtime. This became a common argument for the high correlation found by Feldstein and Horioka (1980). One issue I address here is the potential bias that may result from the failure to control for structural breaks in the univariate series for savings and investment rates.

In the context of the saving-investment relationship only Ozman and Parmaksiz (2003a and 2003b) and Kejriwa (2008) have questioned the stability of the cointegrating relationship. Both authors test for structural breaks in the cointegrating relationship following Hansen and Gregory (1996). My hypothesis is straightforward; the failure to correct for structural breaks in the data will bias the saving-investment relationship towards one. Saving and investment correlations are likely to be affected by global shocks. Instead of restricting the shocks to occur simultaneously for all countries I test each country for unique structural breaks. In general the breaks are associated with changes in growth rates. After removing significant breaks from the data; the savings coefficient is significantly lower; furthermore I apply the results to a simple dynamic adjustment model for savings and investment rates in relation to current account balances.

Since savings and investment rates are influenced by a number of structural breaks the next extension is to optimally estimate the break date. In the previous chapter I showed the variables are likely to have significant level breaks within the context of unit root tests. Testing a series for a unit root controlling for structural breaks will report a break date, but one needs to remember the break date is associated with the objective of minimizing the t-statistic for the unit root coefficient. These tests are not optimal for estimating the actual break date. Unit root tests are complete once non-stationary is rejected independent of the significance level for the coefficient measuring the break date. Furthermore, testing for unit roots with a level breaks has only a developed asymptotic distribution for up to two breaks, more than two breaks usually requires a bootstrapping procedure. In order to test for structural breaks I propose the multiple change method from Bai (1999). This procedure allows for a large number of break points, partial model break estimation, trending regressions, and nonstationary variables. The latter is sufficient as long as the variables are regime wise stationary.

The objective of this chapter is the following: first I will optimally estimate changes in the mean of saving and investment rates. Second both variables will be demeaned accounting for the optimal structural breaks and then the traditional saving-investment regressions are estimated. In addition to estimating each variable independently the traditional saving-investment regression will be estimated for structural changes. Estimating changes in the joint relationship will allow me to examine how capital mobility has changed over time. Finally, I present results for a dynamic model measuring the short-run relationship between savings and investment rates with current account imbalances.

The demeaning process controls for exogenous shocks found under the estimation procedures following Bai (1999). After controlling for exogenous shocks the savings coefficient shows a large and significant decline for most countries. This provides strong evidence that the high correlation from saving-investment regressions can be explained by the failure to control for structural breaks most likely associated with global factors. Clearly, saving and investment rates are jointly affected by additional variables. Failure to account for these additional variables will bias the savings coefficient toward unity, thus bring us full circle to the spurious regression concerns of Miller (1988). Controlling for structural breaks allows for better estimation in regards to the short-run dynamics.

The rest of the chapter proceeds as follows. Section 2 reviews the methodology in Bai (1999). Section 3 presents the test results for the mean shift model applied independently to saving and investment rates. Additionally I examine the significant break dates to test for common factors that cause each variable to shift. Lastly, 88 the results are presented for the demeaned saving-investment regression. Section 4 extends the methodology to test for structural change in the context of the saving- investment regressions. The results present evidence in favor of the global factors hypothesis. Finally Section 5 concludes.

Methodology

Visual inspection of savings and investment rates suggest the data are noisy and suspectable to structural breaks. After concluding both variables are stationary I propose a structural change test to control for exogenous breaks. In the previous chapter I have shown the variables are likely to have significant level breaks within the context of unit root tests. Testing a series for a unit root while controlling for structural breaks will report a break date, but one needs to remember the break date is associated with the objective of minimizing the t-statistic for the unit root coefficient. These tests are not optimal for estimating the true break date. Unit root tests are complete once non-stationarity is rejected independent of the significance level for the coefficient measuring the break date. Further, testing unit root tests with breaks have only developed asymptotic distribution for one and two breaks. In order to test for structural breaks the multiple change method from Bai

(1999) is implemented. This procedure allows for a large number of break points, partial model break estimation, trending regressions, and non-stationary variables.

The next step is to remove the breaks via a demeaning process which will control for exogenous shocks. After controlling for exogenous shocks the savings coefficient shows a large and significant decline for most countries. This provides strong evidence that the high correlation from saving-investment regressions can be explained by the failure to control for structural breaks. Clearly, saving and investment rates are jointly affected by additional variables. Failure to account for these additional variables will bias the savings coefficient toward unity.

Inevitably, saving and investment rates are likely to be individually and jointly affected by a number of global and country specific shocks. Many macroeconomic variables are affected by the existence of cross-country linkages. If these shocks affect both variables within a close time period, saving and investment rates will appear to be highly correlated in the short-run. The high correlation does not necessarily imply capital is immobile. Most authors testing the saving-investment relationship have ignored exogenous shocks, concluding saving and investment rates are perfectly correlated. One approach to control for global shocks is to assume all countries are affected equally. This is often done through sample splitting around key events. In a panel framework it is possible to allow for varying slope and intercept coefficients, but this assumes shocks affect all countries at the same time.

The univariate series for saving and investment rates are tested independently in order to allow for multiple break heterogeneity across countries.

There are a number of methods to test for optimal break dates.[1] Bai (1999) proposes a likelihood-ratio-type test for multiple changes.[2] The test proposed by Bai is unique in that the null hypothesis assumes l break points, whereas the alternative hypothesis assumes $l+1$ break points. Given the structure of the null hypothesis the test can be preformed why augmenting l and consistently estimating break dates. The test does not assume the $l+1$ break point resides within one of the l subsamples. Instead, the test simultaneously estimates l breaks under the null and simultaneously estimates $l+1$ breaks under the alternative. The testing procedure is consistent for dynamic regressors. Previous literature assumed the variables were stationary under the null, but in a dynamic setting once a shift occurs the regressors cease to be stationary. This procedure allows for shifts under the null hypothesis when both the dependent and explanatory variables are non-stationary. Finally, Bai considers testing multiple breaks in polynomial trends.

[1]For a thorough review of structural break tests see Bai (1999) and the cites within.

[2]The test is an exact likelihood ratio test under the assumption of normality. Bai does not assume normality (see p.300).

Following Bai, the m-break model is estimated:

$$
\begin{aligned}
y_t &= z_t^{'}\delta_1 + u_t, \qquad t = 1, 2, ..., k_1^0, \\
y_t &= z_t^{'}\delta_2 + u_t, \qquad t = k_1^0 + 1, ..., k_2^0, \\
&\vdots \\
y_t &= z_t^{'}\delta_{m+1} + u_t, \quad t = k_m^0 + 1, ..., T,
\end{aligned}
\tag{IV.1}
$$

where y_t is the observed independent variable at time t; z_t (q x 1) is a vector of covariates; δ_j $(j = 1, ..., m+1)$ is a vector of coefficients with $\delta_i \neq \delta_{i+1}$ $(i = 1, ..., m)$; and u_t is the disturbance at time t. The break points $k_1^0, ..., k_m^0$ and the number of breaks m are unknown.

The model is estimated for all break date combinations. The optimal break date is found by minimizing the sum of squared residuals for the m equations. The hypothesis consists of testing the null, $H_0 : m = l$, against the alternative, $H_1 : m = l + 1$. The test statistic is based on the difference between the optimal sum of squared residuals associated with l breaks and the optimal sum of squared residuals associated with the $l + 1$ breaks. The test statistic is a standard likelihood ratio tests when the errors are i.i.d. normal random variables.[3] The optimal break point is significant for large values of the test statistic. It is important to note the critical values depend on the number of regressors, π, which is the minimum percent

[3]Critical values are obtained from Bai (1999), p.304-5.

of observation within each break point (selected to be .05), and the relative location of the l and $l+1$ break points. Up to three breaks are tested.

In order to appropriately model the saving-investment regressions the structural break procedure is first applied to test for shifts in the mean of savings and investment rates. Next, the breaks will be removed from the data by mean differencing each series accordingly. The demeaned data are used to test the saving-investment regression. Finally, the mean differenced series are used to measure the short-run dynamic adjustment process of external imbalances.

Breaks in Savings and Investment Rates

The focus of these results are for 24 OECD countries from 1950-2004.[4] Data are from the Penn World Table 6.2. Six OECD countries including Korea, Mexico, Czech Republic, Slovak Republic, Poland, and Hungary are omitted from the sample due to the lack of data availability. The results for the likelihood ratio test statistics for the remaining 24 countries are reported in Tables 4.1 and 4.2. The optimal break dates are also reported.

Table 4.1 presents the results for multiple breaks tests in the mean of savings rates by country. As expected, most countries have a minimum of two significant break dates, and most countries display evidence of three significant breaks. Belgium is the only country to have a constant mean, which is consistent with a

[4]Data for Germany are from 1970-2004.

level stationary savings rate reported in chapter 3. Finland, Turkey, and the United States fail to reject one structural break at the 5% level. Australia, Germany, and Netherlands show evidence of two significant breaks. A large number of countries reject two break points in favor of the alternative of three breaks. It is important to reiterate both variables are expressed relative to gross domestic product. A significant negative shock will appear for sufficiently large increases in output relative to savings or investment, or sufficiently large decreases in savings and investment relative to output. Also it is worth noting savings is calculated from the national accounting identities as the residual of gross domestic product less consumption and government spending which implies the savings rate may shift from changes in these variables.

There are a number of notable break dates. For example, Australia experienced a boom in their manufacturing sector following World War II. In 1960 the economy experienced growth in the manufacturing sector which translated into a rapid development of the mining industry. The mining boom suddenly ended in 1974 causing Australia to enter into a major recession. The results show savings rates increased throughout the boom, but experienced a large decline in 1974. Canada had a noticeable decrease in savings rates from 1991 through 1995. Canada experienced a 4% decline in 1991 but from 1995 through 2004 saving rates increased on average by 6%. The large fall in Canada's savings rate is most likely contributed to the recession in 1991. Attempts to expand the economy lead to large government deficits, but eventually the government began running surpluses in 1996. This is consistent with the shifts in savings rates.

Denmark had savings rates increase in 1959, decrease in 1975, and increased again 1987. The first two shifts can be explained by looking at the business cycle. Denmark had unemployment at low as 2% from 1959-1974, but experienced a rapid increase in unemployment in 1975 through 1985. Unemployment peaked at 12% in the early 1990's. In additional to the rapidly growing unemployment rate, in 1987 the current account moved from a deficit of 5% to 3% surplus. In 1987, Denmark made a concerted effort to increase private savings rates. One reform was aimed at reducing the level of tax deductable interest on private debt. This lead to a collapse in the housing market and a long period of uncertainty. The uncertainty caused a large increase in private savings. Savings rates increased on average by 6% from 1987 through 2004.

Portugal also suffered from excess government spending. Until 1974 the country had an average savings rate of 20.6% but from 1974 through 1978 the average savings rate dropped to 8.9%. Portugal had overextended their arm forces fighting to maintain three African colonies. Further exasperating the problem were domestic issues in which the authoritarian government was overthrown.

The four examples display evidence the shocks are closely related with business cycle events. There is not one common break date across the set of countries. Previous studies electing to exogenously split the sample have chosen 1973, the ending of Bretton Woods. In fact, 1973 does not appear as a significant break date, but nine countries have experienced a break in savings rates from 1974-1976. The 1974-1976 break dates are more likely a result from the first major oil crisis. Other popular break dates revolve around the World War II recover from 1956-1962, the 1979 oil crisis and 1991 global recession.

To help gain a better understanding of the break dates, Figures 4.1 and 4.2 plot savings rates, growth rates, and savings break dates. The break dates are marked by vertical lines. Growth rates were selected as saving rates are likely to be closely affiliated with changes in gross domestic product. When comparing savings rates with growth rates an endogeneity issue does cause some concern. The causality between savings and growth rates is not well defined. The Classical view argues that changes in savings rates cause a change in growth rates. Newer models place emphasis on investment leading output growth while savings respond to changes in output. It is important to note significant changes in growth rates do not always lead to a structural shift in savings rates, but there appears to be evidence shifts in savings rates are closely associated with changes in growth rates. The causality between savings and growth is not rigorously explored here and will not largely effect the results.

It is unclear if savings rates should respond positively or negatively from growth rate shocks; this is evident in the figures below. For example, Denmark has a positive shift in savings rates in 1959, which is correlated with the end of a large business cycle expansion. Savings rates were higher from 1959-1975 while average growth rates declined. Denmark had a large increase in savings rates after 1987 while the country suffered a long period of high unemployment. Conversely, from 1986-2004 United Kingdom had a lower mean savings rates, corresponding with lower growth rates. One explanation could be agents within Denmark were attempting to increase precautionary savings during lower growth periods while UK residents attempted to smooth consumption.

The likelihood ratio test statistics for structural breaks in investment rates are report in Table 4.2. Investment rates appear to be more stable, less breaks, compared to savings rates. Australia and Canada have a constant mean and were reported level stationary in chapter 3. Iceland, Luxembourg, New Zealand, Netherlands, and Spain have one significant break point. Austria, Denmark, United Kingdom, and United States have two significant structural breaks. A number of countries have three significant break points. It is not surprising to find more variability in saving rates then investment rates. In the event of an economic slowdown most individuals will decrease their savings and attempt to smooth consumption. Conversely, the paradox of thrift suggests if individuals expect a slowdown they will increase savings and make the recession self-fulfilling.

At first inspection the late 1970's through the early 1980's are characterized by declining investment rates. Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Italy, Netherlands, New Zealand, Norway, Spain, Sweden, Turkey, and United Kingdom all experience large declines during these period. Clearly, a number of countries were affected by the multiple oil shocks during this period, but more importantly the timing of the shocks does not affect the countries simultaneously. Countries first experienced a downward shock in 1977, but some did not have a significant slowdown until 1982. Another consistent break date appears from 1956-1960. Austria, Belgium, Denmark, Finland, France, Greece, Ireland, Japan, Portugal, Spain, Switzerland, and United Kingdom had a positive significant break in investment rates. This was a common time period in which most countries started to rebound from World War II. In particular Japan experienced a steady increase in investment rates in 1960 and 1967. In the early 1990's Japan's housing market collapsed and both savings and investment rates shifted down to lower levels in 1994.

To understand country specific break dates Figures 4.3 and 4.4 plot investment rates with growth rates and the significant break dates for investment rates. Changes in investment rates should be highly correlated with the business cycle, albeit with a slight lag. Given the large number of breaks from 1956-1960 and 1977-1982 it's not surprising to see the break dates occur during major changes in the business cycle. One extreme example comes from Finland. In 1991 the country experienced a 10% decline in investment rates and an extremely large decline in economic growth as the country struggled through exchange rate crises. Continuing with the Scandinavian countries, Norway and Sweden also saw investment rates drop suddenly in 1990 and 1991, respectively. Norway had investment rates drop nearly 10% resulting from their exchange rate troubles. In addition to the major global events already mentioned the trend between large declines in growth rates with a decrease in investment rates is also clearly evident for Germany in 1974, Italy in 1965, Japan in 1994, New Zealand in 1966, and Switzerland in 1975. Switzerland's decline in investment rates corresponds with a 7.5% contraction in growth rates associated with the 1973 oil crisis.

Investment rates are expressed relative to GDP, in order for a significant shift to occur it must be investment rates change at a faster rate then GDP. This explains why investment rates appear to exhibit large negative shifts when growth rates suddenly decline. When growth rates increase it appears investment rates gradually shift to a higher level. This is consistent with most growth models. Investment rates tend to fall when output suddenly declines and gradually increase as output moves to a higher steady state. Because it takes time for capital to expand there are fewer examples of sudden a increase in investment rates associated with high economic growth. For instance, Greece had investment rates increase nearly 10% in 1959 and another 6% in 1964 while the country had their economic miracle through 1973. Nevertheless, the dates corresponding with the changes in investment rates are after the beginning of the start to the high growth period.

It is worth pointing out there appears to be very little evidence investment rates increased immediately following the breakdown of the Bretton Woods System.

Saving rates appeared to be more affected after the breakdown. Possible explanations savings rates decreased while investment rates remained unchanged could be a large flow of capital from rich to poor countries. A more likely explanation comes from the 1973 oil crisis. As energy prices increased both private and public savings levels decreased which eliminated the excess funds that would have been invested abroad.

Through the 1950-2004 period breaks in the investment rate series can be mapped to changes in the business cycle. Most of the countries in this sample are highly developed with a similar marginal productivity of capital. Thus, changes to policies targeting increased capital flows are likely to have a small impact on investment rates. There are a few exceptions. Denmark's decision to lower the tax incentives for private debt contributed to a current account reversal. In additional to creating added levels of precautionary savings the country lost large amounts of foreign investment. United States had investment rates increase in 1997 which is correlated with high measures of trade openness and the dot com boom. There were a number of global events that occurred during the 1990's which may have contributed to a large amount of international investment for the United States. Japan's financial crisis, East Asian crises, Peso problems, Russia's default, and other emerging market problems started a flight to quality for United States assets.

Saving-Investment Regressions

After presenting the results for breaks in savings and investment rates independently the series are mean differenced to test the savings-investment relationship. The high correlation found by FH and many others is exaggerated from the presence of structural breaks. Table 4.3 presents the results for the original saving-investment regressions and the updated regressions using the mean differenced series. The results are striking, for all but three countries the savings coefficients are either equal or significantly lower. The largest change is seen in Finland, Germany, Italy, and Netherlands. All five countries originally had savings coefficients near unity and after controlling for structural breaks the coefficients are insignificant from zero. Only Canada, Denmark, and United States saw a modest increase in the savings coefficient. Overall, Australia, Finland, Germany, Iceland, Ireland, Italy, Netherlands, and Norway have coefficients insignificant from zero. With the exception of Canada, Japan, and Switzerland every country has a savings coefficient insignificant from one. Japan has very low capital mobility despite a large trade sector, Canada and the United States both show evidence of the large country effect, and meanwhile Switzerland presents a puzzle.

The results present strong support in favor of capital mobility. The logic for this result is straightforward. The high correlation that was found by Feldstein and Horioka was biased upward from the failure to remove significant breaks from the data. The most plausible explanation to date is the existence of a long-run budget constraint. In the long-run, savings and investment rates must converge; in the context of the FH puzzle this appeared as a high savings coefficient. Directly this assumes countries have a stable current account balance, but since the removal of a number of capital restrictions in the 1970's and 1990's current account balances have been relatively volatile. As long as countries have the ability to run external imbalances, the savings coefficient will differ from unity, the long-run budget constraint may not be binding for 20 to 30 years.

In addition to presenting the savings coefficient for both data sets, Table 4.3 reports the mean of the absolute value for each country's current account balance. It is possible to have a high savings coefficient even when a country has a current account imbalance. The point of this exercise is to show countries with lower savings coefficients also have a high mean current account balance (calculated using absolute values). Ireland and Luxembourg have the lowest savings coefficient and the highest average current account balance. Japan and United States have lower average current account balances and the highest savings coefficients. Switzerland, considered the world's bank, has a high savings coefficient, 0.75, and also a high average absolute current account balance, 4%. This does not necessarily mean capital is immobile. Switzerland benefits from a stockpile of international savings allowing them to have constant investment rates. Clearly, Switzerland has a high degree of capital mobility. Belgium, Germany, Italy, and United Kingdom have relatively low mean current account balances and savings coefficients.

Dynamic Adjustment Model

Using savings-investment regressions to measure capital mobility is mostly an afterthought to measuring the short and long-run dynamics for external imbalances. Removing structural breaks provides a data set that can be used to measure the effects of external imbalances on changes in savings and investment rates. Removing the structural breaks helps control exogenous shocks. Furthermore, this approach provides a more accurate description of the relationship without interference of policymakers. The next step is to examine the dynamic adjustment process by which the close association between investment and savings is maintained. It is important to measure the speed of external adjustment and magnitude of the response in savings and investment.

Feldstein and Bacchetta (1991) proposed a basic dynamic model to capture the adjustment process for external imbalances. The following equation is estimated:

$$\Delta i_t = \alpha + \gamma(i_{t-1} - s_{t-1}) + \epsilon_t \tag{IV.2}$$

where i and s are expressed relative to GDP. This equation will test the effect of an increase in the external gap, i.e. the current account balance, on investment rates. An increase in the gap will cause interest rates to increase and investment rates to decline. Domestic and international investors will realize a lower marginal product of capital, the high demand for funds will increase the interest rate above the marginal product, and eventually savings will start to increase. It is important to determine if the high interest rate will cause investment to decrease by a greater amount then the increase in savings. The former will be more costly in terms of lower future economic growth. The higher interest rate is more likely to cause domestic investment rates to decline at a faster rate then savings will increase.

Conversely, a current account surplus will eventually be offset by a lower interest rate and a greater increase in investment rates relative savings rates. The decision to save depends on a number of factors in addition to interest rates. Savings rates are the sum of private and public savings. A government's decision to save is based on budget factors independent of the interest rate. Households save for precautionary motives and to meet future demands. Saving as insurance against future economic uncertainty and to meet retirement needs will have very little response to small changes in the interest rate. Instead the lower interest rate will entice more investment as the cost of borrowing funds decreases below the marginal product of capital.

The results for Equation IV.2 are presented in Table 4.5. Diagnostic tests for normality, serial correlation, and ARCH effects are also presented. As expected an increase in the investment-savings gap is consistent with a decline in the change in future investment rates. In most cases the external imbalance experiences a quick adjustment via changes in investment rates.

Countries that experience a quick adjustment are Australia (-0.817), Sweden (-0.816), New Zealand (-0.751), and Portugal (-0.659). These countries can expect a current account imbalance of 4% to decrease investment rates by 2-3% within the first year. Austria (-0.098), Turkey (-0.189), Netherlands (-0.261), and United States (-0.281) have a slower response to an external imbalance. A 4% external imbalance will reduce investment by approximately 1% within the first year. These results do not directly translate into a reduced current account balance as savings rates may also decrease. Feldstein and Bacchetta test the dynamic model pooled across OECD countries and report a coefficient of (-0.221), but for a sample of quarterly U.S. data, Gordon (1994) reports a positive but insignificant relationship. The model can also be used to understand the cost of a current account correction. The costs, in terms of an economic slowdown, are likely to increase as investment rates become more responsive to external imbalances. These countries will have difficulty maintaining international funds and will be forced to depend on domestic funding. Countries like the United States have the ability to sustain current account imbalances through international lending channels. These countries have access to cheaper international funds.

It is also important to test the effects of an external imbalance on changes in savings rates. A current account deficit could increase savings rates by driving up the interest rate creating more incentives for private savings or by inducing an increase in government saving by making it more costly to borrow. As previously argued, government savings are not likely to respond to the imbalance. Private savings will often respond slower then investment which implies the adjustment process will occur through changes in investment. In order to test the effects of current account imbalances on changes in savings rates the following equation is estimated:

$$\Delta s_t = \alpha + \gamma(i_{t-1} - s_{t-1}) + \epsilon_t. \tag{IV.3}$$

Using the same logic as before, external imbalances should have a positive but small effect on changes in savings rates. The results presented in Table 4.4 show most countries have a significant, positive coefficient. Countries most likely to experience a quick correction via that savings channel are Norway (0.614), Turkey (0.544), Greece (0.431), Denmark (0.414), Ireland (0.353), and Luxembourg (0.281). These results are not surprising for Denmark, Norway, Ireland, and Luxembourg; all four countries have a surplus of savings and have sustained a current account surplus. Savings does not respond to changes in the current account for Australia, Canada, Finland, France, Germany, Iceland, Italy, Netherlands, New Zealand, Portugal, and Switzerland. A small group of countries will experience a slight increase in savings rates following an increase in external imbalances. These countries include Austria, Belgium, Japan, Spain, United Kingdom, and United States.

Comparing the results across Tables 4.5 and 4.4 provides some intuition for which countries have the ability to run sustained current account imbalances. Countries that have low adjustment coefficients in Equations IV.2 and IV.3 have the ability to sustain external imbalances. For the most part Austria, Belgium, Netherlands, and United States have coefficients closest to zero. Given the current status of the United States's current account deficit these results are reassuring. As long as the country avoids a sudden shock to investment the country should be able to slowly return to a sustainable current account deficit. Unfortunately, the recent financial crisis could create a large outflow of foreign investment.

Breaks in Saving-Investment Regression

In the previous section savings and investment rates were tested independently for structural breaks and the data were mean differenced to test the saving-investment relationship. This approach provided a long-run savings coefficient significantly different from one. One drawback of this method is the assumption of constant parameters. Another possible approach is to test the joint relationship for structural breaks. In order to test the relationship for structural breaks the multiple change method of Bai (1999) is implemented to allow for varying slope and intercept coefficients. This approach breaks up the savings coefficient to measure the significant changes in capital mobility over time. The test statistics are reported in Table 4.6 and the saving-investment regression estimates are presented in Table 4.7.

Most countries have a large number of significant breaks. Spain is the only country to not have a significant break. Australia and Iceland each have one break. Austria has two breaks, and the remaining countries have three breaks. Unlike the previous univariate structural break tests, the joint test appears to have more uniform break dates across countries. The mid 1950's; the end of Bretton Woods in 1973; the early 1980's; and early 1990's all appear to have a large number of countries experiencing a change in the saving-investment relationship. One concern with the joint relationship is the presence of outliers. Examining Table 4.7 confirms the presence of outliers could be driving the high correlation when constant parameters are assumed.

Nevertheless, the results are informative for number of countries. For example from 1950-1977 the United States has a low degree of capital mobility. From 1977-1990 the measure significant dropped, consistent with increased capital flows. The measure increased throughout the 1990's but again dropped after 1999. This result is consistent with the large amount of capital inflows into the United States following the emerging market crises during the 1990's and the current account deficit. Other countries that appear to be free of outliers are Denmark, Finland, France, Greece, Japan, Sweden, and United Kingdom. Denmark displays evidence of decreasing capital mobility but each coefficient is higher then the restricted coefficient. Finland shows a increasing trend in capital mobility. France had high capital mobility until 1993, after which the savings coefficient increased near unity. Greece has a relatively low degree of capital mobility but from 1978-1999 capital mobility did increase. Japan shows evidence of low capital mobility between 1956-1983 and 1988-2004, and high levels of capital mobility from 1983-1988.

Sweden had a decreasing measure of capital mobility until 1993. After 1993 capital mobility increased.

United Kingdom displays an interesting pattern of capital mobility. From 1950-1964 the country experienced an intermediate level of capital flows. The country saw an increase in capital mobility from 1964-1977. One explanation for the increase in capital mobility was United Kingdom's decision to join the European Economic Community in 1960. The United Kingdom benefitted greatly as they were able to import goods from commonwealth states (Australia, New Zealand, and Canada) and export them to European countries without worrying about large trade barriers. Capital mobility decreased sharply from 1977-1984 during the oil crisis, but increased drastically after recovering from the global recession.

A high degree of capital mobility is also displayed for Canada from 1991-2004, Iceland from 1982-2004, Ireland from 1985-2004, Netherlands from 1975-2004 with a greater measure of capital mobility after 1987, Portugal from 1984-2004, and United Kingdom from 1984-2004. It is evident most countries display a high level of capital mobility in the later time periods. This is consistent with the view of increasing capital mobility following the break down of capital controls in the early 1970's.

Conclusion

I provide a partial explanation for the Feldstein and Horioka Puzzle. The failure to control of exogenous breaks produces biased results toward unity. In addition to finding a lower savings coefficient, results are presented for a simple dynamic model of adjustment. Four countries, including the United States, have a slow adjustment mechanism.

There are a couple of issues that need to be addressed. If one wants to use the savings-investment regressions as a means of interpreting capital mobility it is necessary to address the possibility of information being lost through the differencing process. If the structural breaks are related to a change in capital mobility (i.e. a current account reversal) then the process of testing for individual structural breaks applied to the bivariate model will most likely produce misleading results. Assuming a constant measure of capital mobility would be wrong. One exercise to circumvent this criticism is to test the joint relationship for structural change. This approach often yields nonsensical results which are most likely the presences of outliers. If the structural breaks are caused from factors independent of capital mobility then the results from the univariate break tests will be accurate.

The next potential problem is the assumption of parameter constancy in the dynamic model representation. The assumption is equivalent to ignoring the possibility of agents changing savings and/or investment behavior following a shock. Nevertheless the concern with investment and savings rates following a different dynamic process over time has not been an issue to date. If one is interested in testing for changing behavior the Bai procedure would provide a good starting point. Instead of testing for changes in the mean, it would be more appropriate to consider structural changes in an AR(1) model.

The objective of this chapter was to test savings and investment rates for exogenous mean shifts and apply the result to model short-run dynamics and capital mobility. In the context of the Feldstein-Horioka puzzle, the failure to control for independent structural breaks by country will bias the savings coefficient toward unity. The breaks for savings and investment rates are most likely correlated with changes in the business cycle. After controlling for the exogenous shifts through a mean differencing process the savings coefficient are significantly lower for all but three countries. This suggests that previously estimated savings coefficients are likely to be biased toward unity from the existence of country specific and global business cycle shocks.

After controlling for structural breaks, both variables are modeled in a simple dynamic model to test external imbalances on changes in future investment and savings rates. Removing the breaks from the data allows for a more accurate representation of the short-run behavior for each variable. This method produces accurate estimates as long as countries avoid sudden shocks. The adjustment mechanism is likely to occur through changes in investment rates, but for some countries a lower cost adjustment through changes in savings rates is found. Combining the results of both tests, four countries have the ability to maintain a sustained imbalance, including the United States. Lastly, the structural break tests are applied to the joint relationship to measure the change in capital mobility over time. The results suggest the saving-investment relationship is likely biased due to outliers. A number of countries have spurious results in which the savings coefficients are greater than unity. This further emphasizes the importance of using structural break tests to control for exogenous shocks independently. The savings coefficient does decline over time and later time periods are correlated with a higher degree of capital mobility.

Failing to control for structural breaks provides another possible explanation for the high savings-coefficient found by Feldstein and Horioka. Applying the structural breaks to mean difference the data allows for the short-run dynamics between external adjustments and changes to investment and savings rates to be estimated. This approach is useful for measuring how quickly countries can expect external imbalances to adjust to their long-run equilibrium values independent of shocks.

Table 4.1. Likelihood Ratio Test for Breaks in Savings Rates

Country	TB_1	LR_1	TB_{2a}	TB_{2b}	LR_2	TB_{3a}	TB_{3b}	TB_{3c}	LR_3
Australia	1973	36.20***	1961	1974	21.60***	1961	1974	2001	4.30
Austria	1954	60.08***	1955	1960	8.70*	1955	1969	1981	20.96***
Belgium	1954	7.02	1981	1988	47.36***	1955	1981	1988	28.18***
Canada	1994	49.76***	1979	1999	26.08***	1979	1991	1995	11.48**
Denmark	1958	43.60***	1959	1995	33.58***	1959	1975	1987	30.76***
Finland	1984	77.28***	1991	1995	6.85	1983	1991	1995	23.99***
France	1957	36.40***	1959	1980	69.84***	1959	1981	1988	12.64**
Germany	1974	121.64***	1975	1981	22.52***	1975	1981	1986	7.79
Greece	1981	57.92***	1961	1982	72.74***	1957	1964	1982	12.06**
Iceland	1981	79.68***	1954	1982	31.20***	1954	1982	1991	14.89***
Ireland	1987	131.85***	1982	1995	55.76***	1961	1982	1995	71.05***
v Italy	1979	85.02***	1955	1980	34.38***	1955	1971	1981	72.86***
Japan	1960	153.68***	1960	1967	22.44***	1960	1967	1994	49.10***
Luxembourg	1961	16.72***	1975	1989	86.55***	1975	1988	1997	25.62***
Netherlands	1975	30.42***	1959	1975	68.16***	1954	1959	1975	9.66*
New Zealand	1959	19.52***	1974	1983	13.19**	1960	1974	1983	13.01**
Norway	1985	11.13**	1986	2000	29.18***	1980	1986	2000	22.80***
Portugal	1973	11.20**	1963	1974	41.37***	1963	1974	1978	41.28***
Spain	1959	55.78***	1961	1980	25.98***	1960	1968	1976	20.35***
Sweden	1975	15.17***	1976	1995	36.95***	1959	1976	1995	24.65***
Switzerland	1954	83.25***	1954	1960	23.36***	1954	1960	1975	12.18**
Turkey	1986	62.04***	1956	1987	9.55*	1974	1977	1987	64.64***
United Kingdom	1955	55.50***	1956	1986	24.48***	1956	1964	1986	16.19***
United States	1981	14.52***	1978	1982	6.34	1982	1995	2001	12.47**

Critical values are calculated in Bai (1999), p. 304-305.
*,**,*** indicate 10%, 5% and 1% significance.

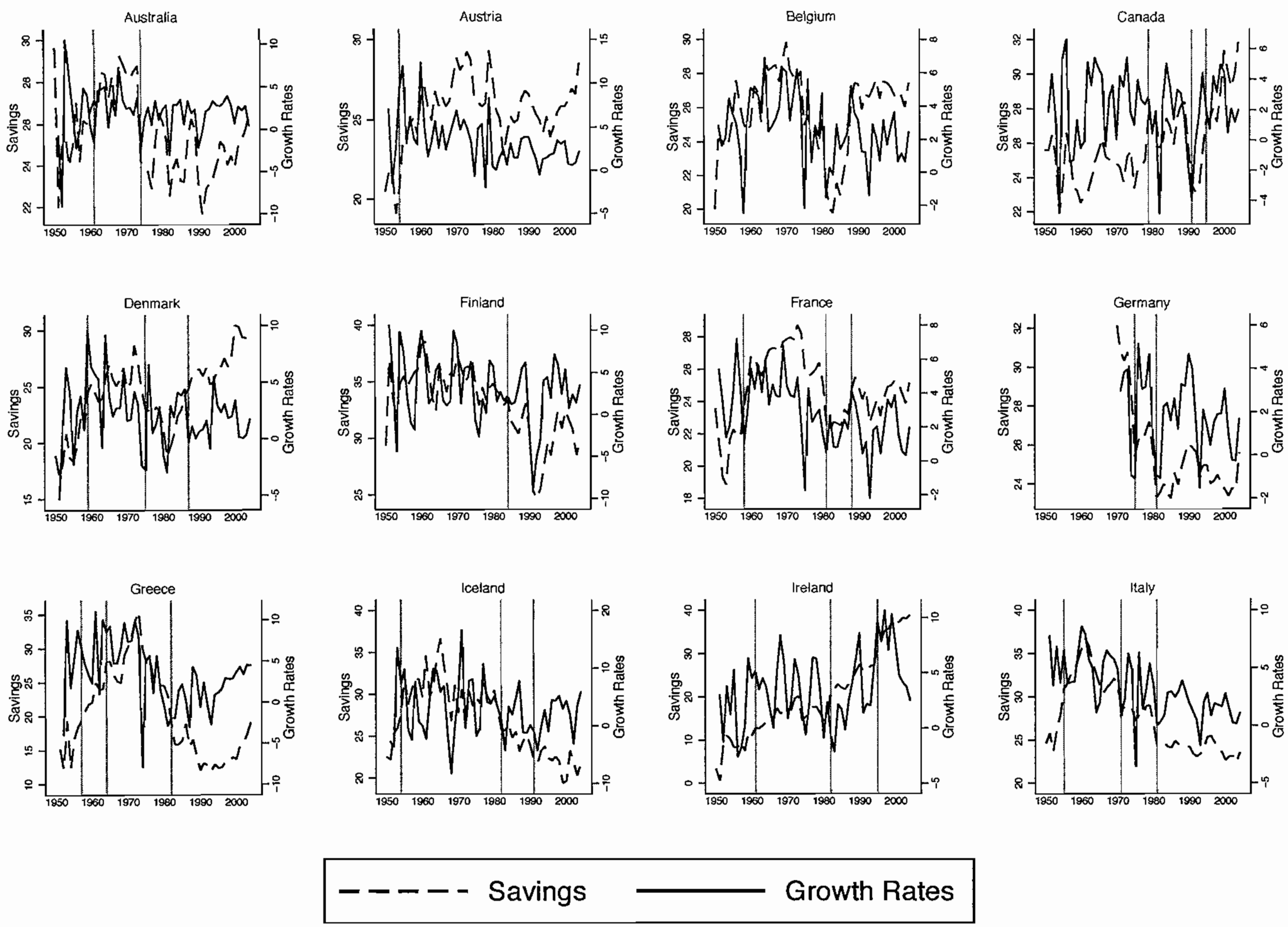

Figure 4.1. Saving Breaks and Growth Rates, Australia - Italy

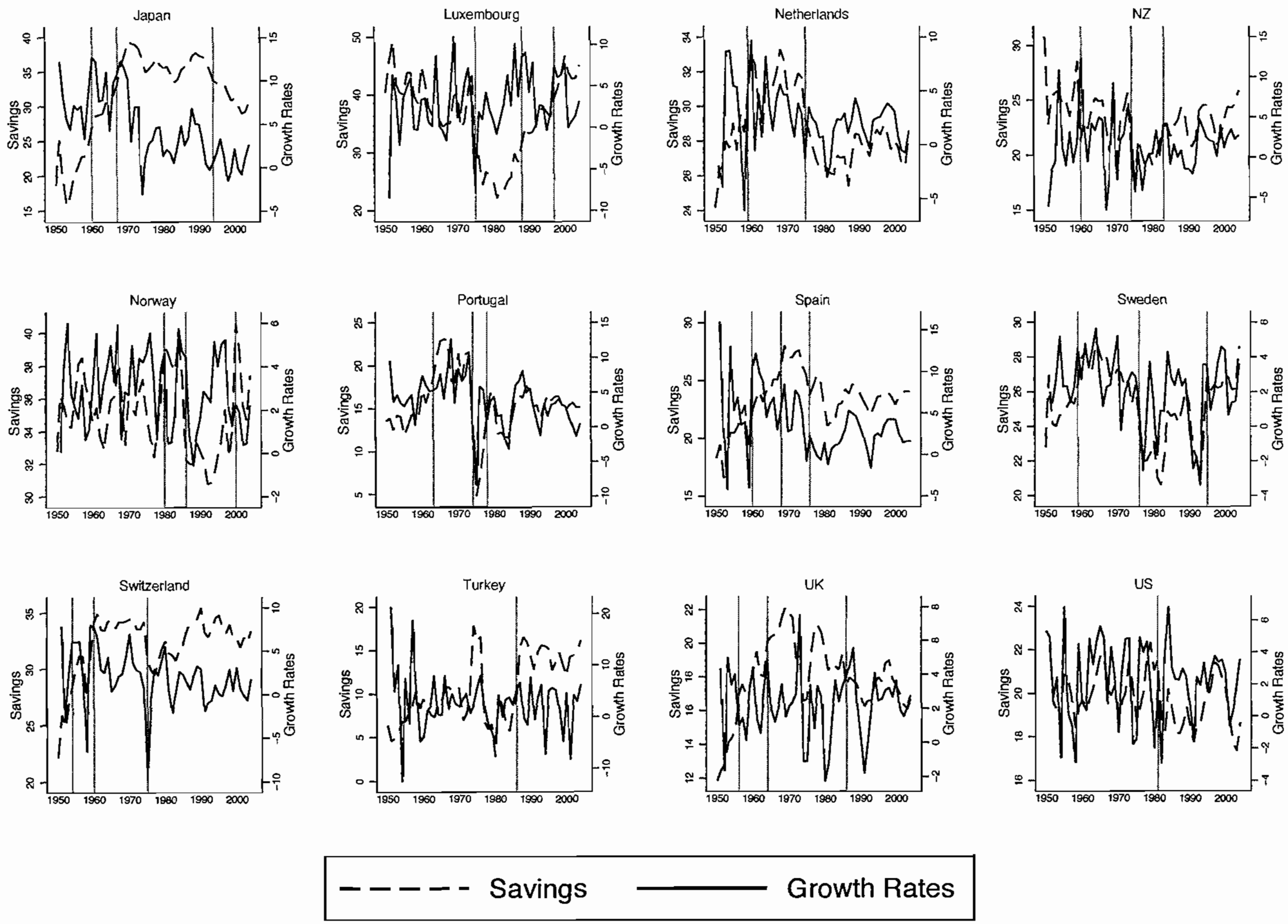

Figure 4.2. Saving Breaks and Growth Rates, Japan - U.S.

Table 4.2. Likelihood Ratio Test for Breaks in Investment Rates

Country	TB_1	LR_1	TB_{2a}	TB_{2b}	LR_2	TB_{3a}	TB_{3b}	TB_{3c}	LR_3
Australia	1973	8.87	1964	1971	8.08	1958	1974	2001	4.08
Austria	1959	15.07***	1960	1982	37.01***	1960	1970	1982	5.91
Belgium	1980	52.94***	1960	1981	18.30***	1960	1982	1988	17.46***
Canada	1957	2.33	1960	1974	8.37	1956	1959	1974	6.38
Denmark	1958	17.87***	1959	1980	95.52***	1959	1980	1997	9.49
Finland	1990	197.54***	1977	1991	17.94***	1956	1977	1991	27.35***
France	1955	32.30***	1960	1981	41.82***	1956	1964	1981	17.08***
Germany	1981	59.86***	1981	1996	39.38***	1974	1982	1996	22.89***
Greece	1980	20.71***	1960	1981	112.40***	1959	1964	1979	13.19**
Iceland	1982	93.09***	1955	1983	7.40	1955	1976	1983	10.16*
Ireland	1962	29.25***	1968	1985	39.11***	1963	1969	1985	15.40***
Italy	1980	118.34***	1965	1983	12.79**	1955	1965	1983	58.65***
Japan	1960	144.78***	1961	1998	21.92***	1960	1967	1994	34.21***
Luxembourg	1966	108.54***	1961	1967	3.02	1967	1987	1994	7.89
Netherlands	1980	114.96***	1975	1981	9.91*	1960	1972	1981	26.05***
New Zealand	1966	13.81***	1959	1977	3.07	1967	1973	1976	12.09**
Norway	1988	151.88***	1978	1990	31.01***	1974	1978	1990	22.35***
Portugal	1959	41.18***	1960	1983	2.83	1960	1984	1987	20.85***
Spain	1960	35.72***	1962	1978	33.85***	1954	1962	1978	17.28***
Sweden	1976	94.83***	1977	1991	25.82***	1955	1977	1991	21.72***
Switzerland	1954	19.79***	1960	1975	30.74***	1955	1960	1975	12.82**
Turkey	1986	48.30***	1966	1987	13.83**	1974	1977	1987	84.29***
United Kingdom	1958	45.01***	1960	1980	17.25***	1955	1964	1975	10.91*
United States	1996	31.90***	1977	1997	13.12**	1977	1990	1996	8.25

Critical values are calculated in Bai (1999), p. 304-305.
*,**,*** indicate 10%, 5% and 1% significance.

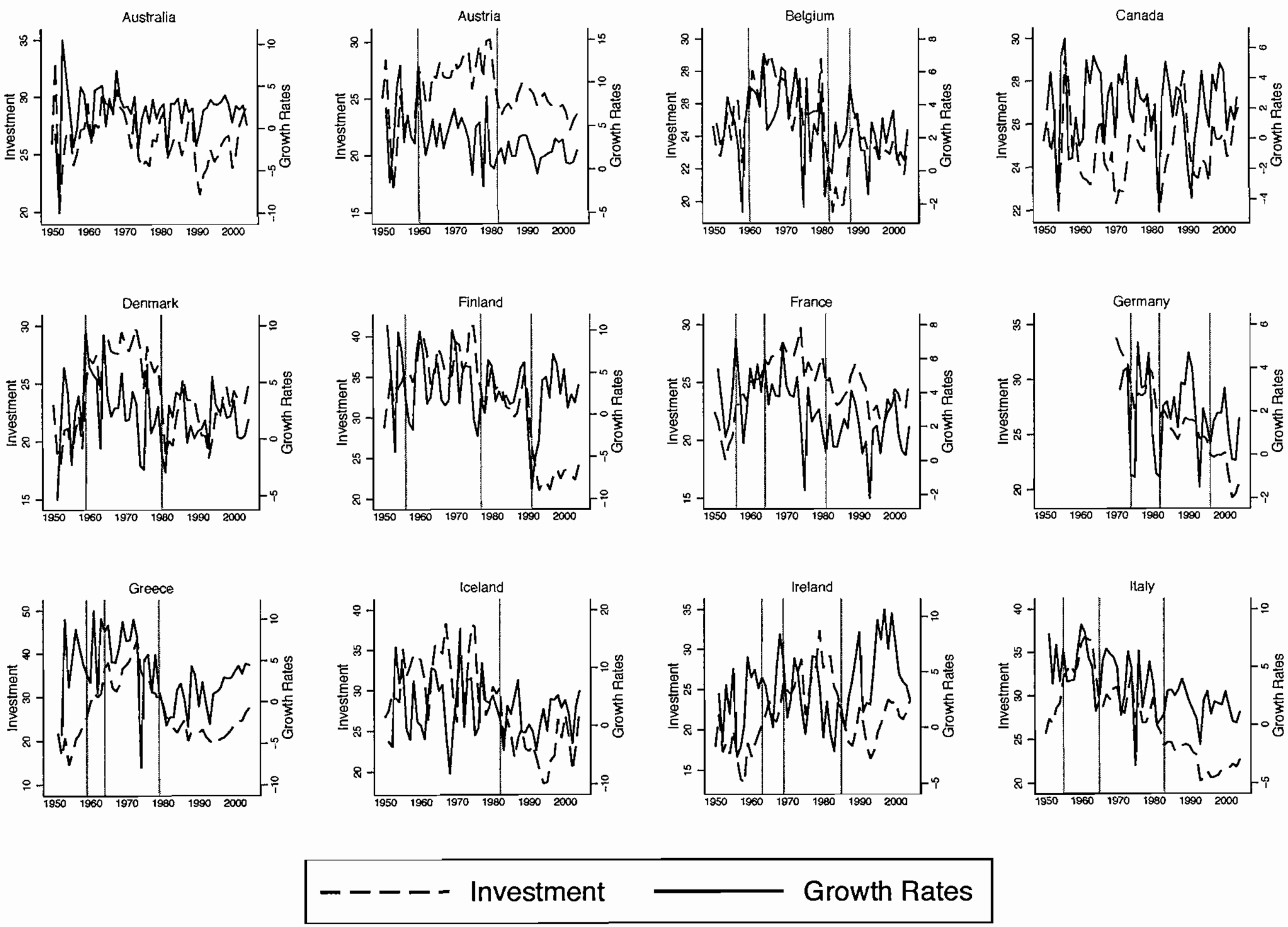

Figure 4.3. Investment Breaks and Growth Rates, Australia - Italy

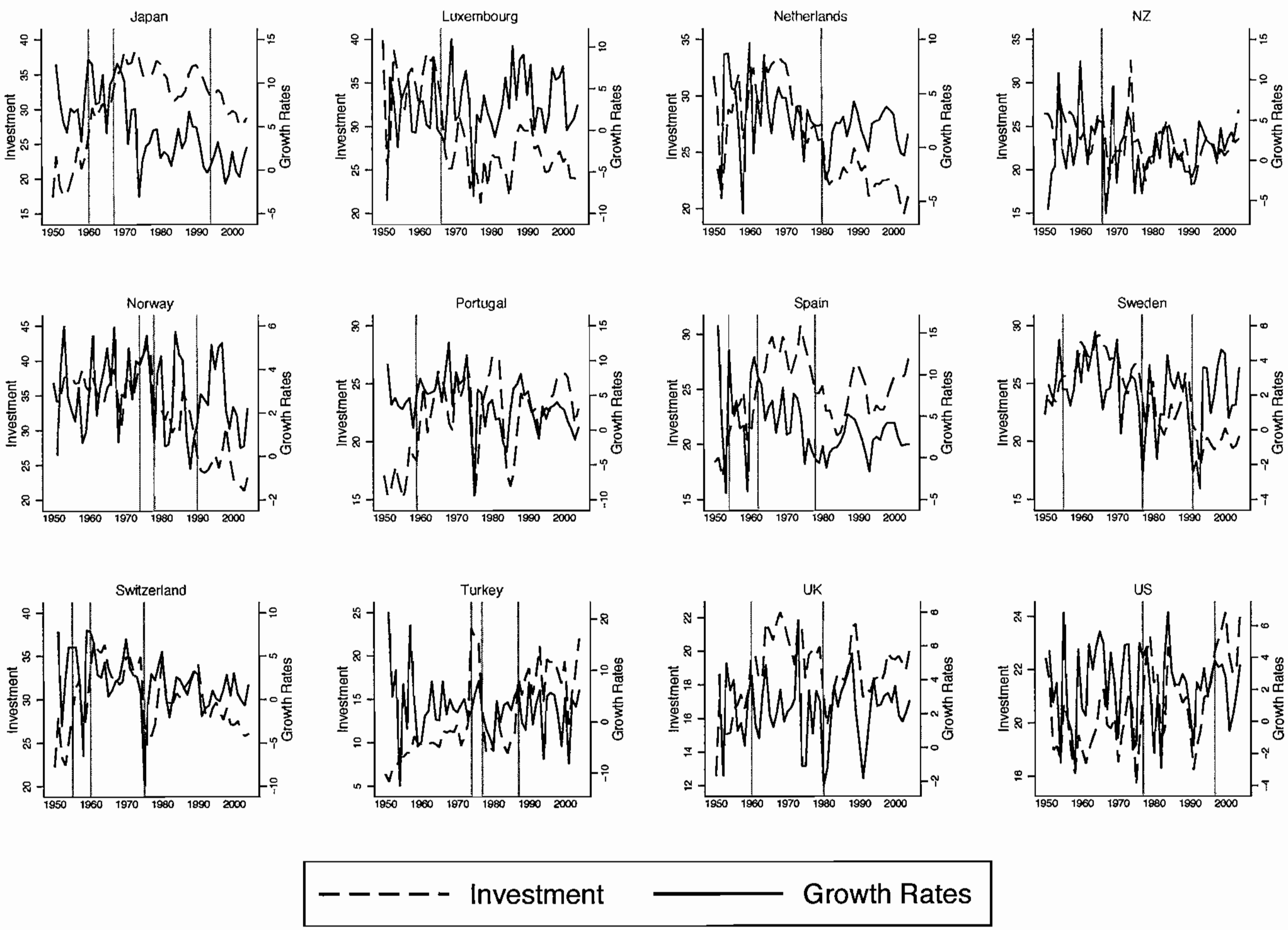

Figure 4.4. Investment Breaks and Growth, Japan - U.S.

Table 4.3. Saving-Investment Regressions

Country	Levels β	Levels R^2	Demeaned β^{dm}	Demeaned R^2	Current Account
Australia	0.606 (0.142)	0.255	0.430 (0.243)	0.056	2.214
Austria	0.769 (0.120)	0.436	0.351 (0.134)	0.115	1.649
Belgium	0.585 (0.110)	0.348	0.177 (0.069)	0.110	1.678
Canada	0.364 (0.083)	0.264	0.737 (0.148)	0.318	2.002
Denmark	0.468 (0.122)	0.218	0.646 (0.125)	0.334	2.812
Finland	1.544 (0.141)	0.693	0.270 (0.123)	0.084	2.668
France	0.942 (0.078)	0.732	0.631 (0.146)	0.259	1.050
Germany	1.218 (0.165)	0.623	0.217 (0.233)	0.026	1.182
Greece	0.971 (0.048)	0.886	0.581 (0.129)	0.282	4.186
Iceland	0.960 (0.111)	0.585	0.432 (0.235)	0.060	4.009
Ireland	0.066 (0.056)	0.025	-0.155 (-0.122)	0.030	8.027
Italy	1.072 (0.064)	0.842	0.321 (0.170)	0.063	1.529
Japan	0.912 (0.026)	0.960	0.861 (0.078)	0.697	1.020
Luxembourg	0.209 (0.094)	0.086	-0.515 (-0.111)	0.288	7.928
Netherlands	1.313 (0.205)	0.436	0.139 (0.296)	0.004	2.586
New Zealand	0.460 (0.137)	0.175	0.482 (0.188)	0.110	2.109
Norway	0.233 (0.324)	0.010	0.327 (0.177)	0.061	6.901
Portugal	0.533 (0.118)	0.277	0.560 (0.193)	0.137	3.975
Spain	1.114 (0.100)	0.700	0.545 (0.182)	0.145	1.711
Sweden	0.727 (0.176)	0.244	0.590 (0.127)	0.291	3.384
Switzerland	0.960 (0.129)	0.511	0.787 (0.213)	0.205	4.465
Turkey	1.098 (0.075)	0.804	0.225 (0.092)	0.101	3.213
United Kingdom	0.662 (0.086)	0.530	0.334 (0.150)	0.086	1.271
United States	0.517 (0.155)	0.174	0.757 (0.083)	0.609	1.347

Standard Errors are in parentheses.
The absolute value of the current account is used to calculate the mean
β is from an OLS regression of investment on savings.
β^{dm} is from an OLS regression controlling for breaks.

Table 4.4. Dynamic Adjustment of Savings Rates

Country	N	α	γ	Normality	LM(1)	ARCH(1)	R^2
Australia	52	0.070 (0.174)	0.005 (0.110)	1.36	2.110	0.244	0.122
Austria	54	0.042 (0.180)	0.189 (0.097)	0.07	0.077	0.446	0.068
Belgium	53	0.065 (0.184)	0.156 (0.087)	2.06	0.020	3.165	0.125
Canada	52	0.006 (0.171)	0.069 (0.145)	2.31	0.347	0.008	0.233
Denmark	52	0.100 (0.192)	0.414 (0.171)	1.77	0.237	0.003	0.257
Finland	52	0.042 (0.252)	0.134 (0.123)	2.72	4.078	0.196	0.174
France	52	0.041 (0.139)	0.062 (0.137)	13.90	2.275	0.335	0.192
Germany	33	0.019 (0.142)	-0.080 (0.118)	0.45	0.548	0.840	0.039
Greece	51	0.093 (0.325)	0.431 (0.155)	0.69	5.568	8.623	0.268
Iceland	53	0.033 (0.302)	0.074 (0.089)	0.98	2.400	4.097	0.288
Ireland	53	0.238 (0.292)	0.353 (0.089)	3.94	2.157	0.097	0.239
Italy	54	0.010 (0.165)	0.087 (0.091)	7.09	1.010	0.831	0.017
Japan	54	0.020 (0.286)	0.165 (0.256)	18.67	2.024	1.104	0.008
Luxembourg	52	-0.232 (0.326)	0.281 (0.089)	0.43	1.881	2.044	0.434
Netherlands	52	0.023 (0.153)	0.090 (0.072)	0.16	6.176	1.871	0.172
New Zealand	53	0.092 (0.241)	-0.030 (0.124)	1.66	0.996	2.850	0.253
Norway	52	-0.030 (0.187)	0.614 (0.142)	0.87	0.490	0.451	0.298
Portugal	52	0.042 (0.286)	0.000 (0.124)	5.09	3.506	0.019	0.237
Spain	52	0.099 (0.148)	0.144 (0.111)	14.76	2.351	0.000	0.139
Sweden	52	0.057 (0.151)	-0.203 (0.171)	1.62	2.400	0.342	0.163
Switzerland	53	0.013 (0.156)	-0.025 (0.080)	6.40	0.510	0.768	0.153
Turkey	53	0.148 (0.323)	0.544 (0.125)	5.91	0.412	0.683	0.276
United Kingdom	53	0.022 (0.125)	0.207 (0.098)	7.44	1.860	0.184	0.155
United States	54	-0.054 (0.149)	0.182 (0.202)	1.39	0.009	0.770	0.015

Standard errors are in parentheses

Jarque-Bera test is used to test normality. The test statistic is distributed $\chi^2(2)$

The ARCH test is asymptotically distributed as $\chi^2(1)$, null is no ARCH effects

A LM test is asymptotically distributed as $\chi^2(1)$, null is no serial correlation

Table 4.5. Dynamic Adjustment of Investment Rates

Country	N	α	γ	Normality	LM(1)	ARCH(1)	R^2
Australia	54	0.052 (0.276)	-0.817 (0.112)	0.232	1.333	0.010	0.505
Austria	52	-0.041 (0.210)	-0.098 (0.151)	5.733	5.005	0.236	0.338
Belgium	52	0.015 (0.189)	0.083 (0.093)	0.765	1.165	0.078	0.455
Canada	52	0.050 (0.192)	-0.562 (0.179)	5.222	0.021	1.239	0.374
Denmark	52	0.047 (0.221)	-0.314 (0.196)	1.190	0.385	0.050	0.362
Finland	52	-0.003 (0.281)	-0.547 (0.141)	1.074	0.480	0.566	0.353
France	53	-0.016 (0.157)	-0.443 (0.142)	15.820	3.551	0.006	0.164
Germany	34	-0.032 (0.184)	-0.527 (0.144)	0.615	1.284	0.053	0.296
Greece	52	0.145 (0.391)	-0.342 (0.146)	5.142	0.902	0.054	0.153
Iceland	53	0.148 (0.422)	-0.571 (0.125)	9.216	0.713	0.428	0.466
Ireland	54	0.046 (0.299)	-0.307 (0.084)	0.038	0.395	0.066	0.204
Italy	54	0.032 (0.216)	-0.418 (0.120)	3.010	1.321	0.241	0.190
Japan	54	0.037 (0.272)	-0.376 (0.243)	5.661	4.961	1.809	0.044
Luxembourg	54	-0.117 (0.410)	-0.340 (0.077)	64.569	0.526	0.204	0.273
Netherlands	52	0.091 (0.261)	-0.261 (0.123)	19.708	0.087	0.148	0.284
New Zealand	53	0.064 (0.310)	-0.751 (0.141)	8.520	1.398	0.461	0.365
Norway	54	-0.028 (0.289)	-0.464 (0.135)	0.064	0.262	4.439	0.186
Portugal	52	0.036 (0.315)	-0.659 (0.133)	22.147	0.433	0.378	0.405
Spain	53	0.027 (0.189)	-0.508 (0.125)	6.277	2.377	0.094	0.262
Sweden	52	0.044 (0.152)	-0.816 (0.172)	0.238	1.795	0.831	0.411
Switzerland	54	0.006 (0.289)	-0.374 (0.149)	3.392	0.479	1.135	0.109
Turkey	53	0.177 (0.292)	-0.189 (0.113)	3.255	2.980	0.053	0.245
United Kingdom	54	0.070 (0.176)	-0.420 (0.119)	1.091	1.382	0.014	0.192
United States	52	-0.015 (0.160)	-0.281 (0.234)	0.610	2.024	1.445	0.132

Standard errors are in parentheses

Jarque-Bera test is used to test normality. The test statistic is distributed $\chi^2(2)$

The ARCH test is asymptotically distributed as $\chi^2(1)$, null is no ARCH effects

A LM test is asymptotically distributed as $\chi^2(1)$, null is no serial correlation

Table 4.6. Level and Slope Change in Saving-Investment Regressions

Country	TB_1	LR_1	TB_{2a}	TB_{2b}	LR_2	TB_{3a}	TB_{3b}	TB_{3c}	LR_3
Australia	1956	29.16***	1957	1988	5.16	1957	1971	1980	4.11
Austria	1995	29.17***	1954	1996	19.93***	1954	1976	1982	4.35
Belgium	1982	96.39***	1959	1983	11.50**	1954	1979	1983	11.50**
Canada	1960	14.36***	1954	1961	12.67**	1954	1961	1991	13.11**
Denmark	1986	145.79***	1981	1990	12.50**	1960	1981	1990	20.35***
Finland	1992	144.39***	1956	1993	13.89**	1960	1977	1993	10.96*
France	1992	22.91***	1963	1993	31.81***	1956	1963	1993	15.67***
Germany	1985	58.79***	1986	2002	80.63***	1979	1986	2002	21.28***
Greece	1978	66.19***	1960	1978	17.84***	1960	1978	1999	18.37***
Iceland	1982	23.51***	1976	1998	7.66	1973	1976	1998	12.22**
Ireland	1984	42.91***	1969	1985	41.99***	1957	1972	1985	28.38***
Italy	1992	58.25***	1965	1993	16.21***	1965	1983	1993	17.66***
Japan	1982	18.47***	1983	1988	10.34*	1956	1983	1988	9.76*
Luxembourg	1966	127.29***	1967	1987	12.72**	1966	1974	1987	14.76***
New Zealand	1986	13.73	1972	1975	10.10**	1972	1975	1987	12.20**
Netherlands	1980	79.22***	1954	1981	22.59***	1954	1972	1981	16.06***
Norway	1988	166.30***	1978	1990	31.75***	1974	1978	1990	33.48***
Portugal	1969	38.75***	1974	1984	22.88***	1974	1984	1987	25.49***
Spain	1967	7.06	1965	1977	14.23**	1965	1978	1988	12.78**
Sweden	1992	272.79***	1983	1993	32.93***	1954	1983	1993	11.52**
Switzerland	1991	92.47***	1965	1992	16.46***	1955	1965	1992	12.42**
Turkey	1970	21.36***	1971	2001	13.22***	1971	1987	2001	25.13***
United Kingdom	1973	18.33***	1977	1984	9.75*	1964	1977	1984	14.90***
United States	1976	79.99***	1977	1999	78.81***	1977	1990	1999	21.98***

Critical values are calculated in Bai (1999), p. 304-305.
*,**,*** indicate 10%, 5% and 1% significance.

Table 4.7. Saving-Investment Regressions with Structural Breaks

Country	β	β_1	β_2	β_3	β_4	TB_i
Australia	0.606 (0.142)	-0.742 (0.322)	0.833 (0.132)			1956
Austria	0.769 (0.120)	2.794 (0.607)	1.063 (0.121)	-0.371 (0.354)		1954, 1996
Belgium	0.585 (0.110)	-0.368 (0.301)	0.660 (0.125)	1.179 (0.249)	0.581 (0.093)	1954, 1979, 1983
Canada	0.364 (0.084)	-0.987 (1.147)	1.419 (0.257)	0.722 (0.128)	0.309 (0.101)	1954, 1961, 1991
Denmark	0.468 (0.122)	0.700 (0.189)	0.707 (0.158)	0.743 (0.166)	0.815 (0.193)	1960, 1981, 1990
Finland	1.544 (0.141)	0.746 (0.220)	1.001 (0.219)	0.934 (0.129)	0.365 (0.221)	1960, 1977, 1993
France	0.942 (0.078)	0.682 (0.198)	0.412 (0.151)	0.712 (0.076)	0.916 (0.270)	1956, 1963, 1993
Germany	1.218 (0.165)	0.884 (0.093)	1.311 (0.180)	1.666 (0.210)	0.644 (0.430)	1979, 1986, 2002
Greece	0.971 (0.048)	0.885 (0.125)	1.076 (0.083)	0.653 (0.060)	0.809 (0.269)	1960, 1978, 1999
Iceland	0.960 (0.111)	0.624 (0.176)	0.147 (0.337)			1982
Ireland	0.066 (0.056)	-0.329 (0.207)	1.192 (0.178)	-0.186 (0.188)	0.237 (0.073)	1957, 1972, 1985
Italy	1.072 (0.064)	0.841 (0.065)	0.470 (0.114)	0.443 (0.644)	-0.385 (0.320)	1965, 1983, 1993
Japan	0.912 (0.026)	0.645 (0.124)	0.916 (0.032)	0.325 (0.415)	0.956 (0.074)	1956, 1983, 1988
Luxembourg	0.209 (0.093)	-0.723 (0.153)	-0.496 (0.296)	-0.090 (0.115)	-0.314 (0.104)	1966, 1974, 1987
Netherlands	1.313 (0.205)	-2.149 (0.590)	0.825 (0.213)	0.344 (0.264)	0.227 (0.367)	1972, 1975, 1987
New Zealand	0.460 (0.137)	0.522 (0.170)	-1.773 (0.549)	0.626 (0.320)	1.038 (0.317)	1954, 1972, 1981
Norway	0.233 (0.324)	0.546 (0.256)	-0.411 (0.533)	-0.297 (0.191)	-0.345 (0.172)	1974, 1978, 1990
Portugal	0.533 (0.118)	0.956 (0.098)	0.963 (0.159)	0.007 (0.573)	0.248 (0.452)	1974, 1984, 1987
Spain	1.114 (0.100)	1.114 (0.100)				
Sweden	0.727 (0.176)	0.577 (0.279)	0.865 (0.070)	1.146 (0.211)	0.391 (0.133)	1954, 1983, 1993
Switzerland	0.960 (0.129)	0.471 (0.283)	1.578 (0.188)	1.415 (0.157)	1.032 (0.451)	1955, 1965, 1992
Turkey	1.098 (0.075)	0.857 (0.164)	1.116 (0.086)	-0.273 (0.289)	4.531 (0.987)	1971, 1987, 2001
United Kingdom	0.662 (0.086)	0.713 (0.120)	0.321 (0.171)	1.460 (0.388)	0.186 (0.260)	1964, 1977, 1984
United States	0.517 (0.155)	0.921 (0.092)	0.572 (0.108)	1.241 (0.149)	0.590 (0.180)	1977, 1990, 1999

Standard errors are in parentheses.
Regression is a basic OLS regression with savings interacted with significant break dates.
β is from an OLS regression of investment on savings.
*,**,*** indicate 10%, 5% and 1% significance.

CHAPTER V

PANEL ANALYSIS CONTROLLING FOR BREAKS

Introduction

Many attempts have been made to explain the suspiciously high correlation between domestic saving and national investment rates. Feldstein and Horioka's (1980) finding of a high correlation between saving and investment rates among a sample of OECD countries has generated a large body of literature. In the last chapter I showed the high savings coefficient was most likely caused by the failure to account for exogenous structural breaks. The goal of this chapter is to first show that controlling for structural breaks in savings and investment independently causes a lower savings coefficient using panel estimators and second to test trade openness, country size, trade balance, financial openness, and age dependency for threshold effects to explain the remaining correlation. For the first part I take advantage of recently developed panel estimators to measure the effects of structural breaks on the pooled sample and find a significant reduction in the savings coefficient. Additionally letting the savings coefficient depend on country specific characteristics does explain a large portion of the remaining correlation. The panel approach uses dynamic fixed effects, mean group (see Pesaran and Smith, 1995), pooled mean group (see Pesaran, Shin, and Smith, 1997 and 1999) estimators. The second approach uses a threshold testing procedure from Hansen (1999) approach which models testing for non-dynamic threshold effects.

The mean group (MG) and pooled mean group (PMG) estimators are appropriate for data sets with large N and large T dimensions. Furthermore, both estimators represent a dynamic autoregressive lag model and are robust to I(0) or I(1) variables. I assume both variables are level stationary after controlling for structural breaks, but using this approach does circumvent the remaining non-stationarity. The three estimators used are unique. The dynamic fixed effects (DFE) estimator assumes constant slope coefficient and error variances across countries and varying intercepts. MG estimator relies on estimating N time-series regressions and averaging the coefficient, and the PMG estimator combines the previous methods and relies on a combination of pooling and averaging coefficients. Hansen's (1999) threshold testing approach provides the framework for testing saving and investment rates controlling for thresholds effects. Hansen's method is superior to testing the relationship in a country by country or panel framework; the previous estimators fail to optimally estimate sample groupings, instead they rely on arbitrary selections grouping the countries in equal samples.

The saving coefficient decreases after controlling for regime changes in trade openness, country size, age dependency ratios, and trade balances. Furthermore the savings coefficient is lower following the break down of Bretton Woods. These results suggest saving and investment regressions provide intuition behind capital mobility when controlling for thresholds using variables that are correlated with increased capital flows. The saving coefficient is statistically insignificant for countries in the highest grouping of trade openness thus confirming that saving-investment regressions are consistent with other measures of capital mobility.

This chapter provides two main contributions. First, I compare the estimate across a diverse group of dynamic panel estimators controlling for structural breaks found in the previous section. I show the savings coefficient is lower after controlling for the structural break. Second using a procedure developed by Hansen (1999) I show that previous results may produce biased saving coefficients by failing to appropriately split the data when testing the effects of trade openness and country size. Using threshold effects is superior to other methods which randomly select a sample by dividing the data set into arbitrary groupings. I test the relationship for a sample of 22 OECD countries controlling for structural breaks by country and threshold effects arising from trade openness, financial openness, country size, trade balance, and age dependency.

This chapter is organized as follows: Section 2 provides a review the literature associated with using alternative variables to explain the relationship. Section 3 explains the testing procedures for the MG, PMG and threshold effects estimators. Section 5 presents the results for the MG, PMG, dynamic fixed effects estimators, and threshold effects. Finally, Section 5 concludes.

Literature Review

. Many authors have undertook confirmatory analysis by testing the relationship in settings for which capital is expected to be highly mobile. The first extension involved splitting the data by time periods. The break down of the fixed exchange rate system in 1973 provides a nature break point. The savings coefficient should be high prior to the break down of the Bretton Woods system and decrease as more countries remove capital controls. Miller (1988) showed capital mobility increased in the floating exchange rate period. In the last chapter I showed break dates were not consistent across countries. Testing the individual variables for structural breaks and applying the results to the joint relationship resulted in a significant reduction in the savings coefficient.

In addition to testing the relationship across time periods a number of studies group countries by measures of trade openness, country size, and level of development. Bahmani-Oskooee and Chakrabarti (2007) were the last to test trade openness and level of development. They apply fully modified ordinary least squares to samples split into low, medium, and high income countries and by countries that are financially open, closed, and open after initially being closed. They find the saving coefficient lowest for low income countries but find little evidence the savings coefficient varies across levels of openness. AmirKhalkhali and Dar (2007) find no systematic relationship between trade openness and capital mobility. Other explanations include the use of a trend term (Georgopoulos and Hejazi 2005), country size (Tobin 1983, Murphy 1984, Baxter 1993, and Ho 2003), level of country development (Coakley et al. 1999, Kasuga 2004, Mamingi 1997, Payne and Kumazawa 2006), and regime changes (Ozmen and Parmaksiz 2003). Bahmani-Oskooee and Chakrabarti (2005) control for both openness and country size. Vamvakidis and Wacziarg (1998) control for openness and population growth. The above papers succeed in reducing the coefficient on saving, but it remains positive and statistically significant.

Feldstein and Horioka (1980) were the first to present the argument that larger countries are more likely to independently finance capital investment, however they were unable to find a relationship between country size and the saving coefficient. Murphy (1984) argues saving and investment regressions implicitly assume demand and supply for capital goods are inelastic, price levels are fixed, and the real interest rate is set at the world interest rate. Applying the latter assumption to large countries drives the high correlation between saving and investment rates. Large countries have the ability to influence world prices and interest rates thus biasing the savings coefficient toward unity. Using a sample of 17 OECD countries Murphy finds the coefficient on saving to be significantly higher for large countries.

Large countries have more developed financial markets which increases the likelihood domestic saving will finance national investment. There are a couple of different methods for testing how country size affects the relationship. The first method requires the use of country fixed effects which will not only control for size, but also account for other unobservable effects that are constant over time. This makes it infeasible to estimate the magnitude of the size effect. Ho (2003) uses a threshold model interacting savings rate with dummy variables representing large, medium, and small countries. Ho finds large countries have significantly higher saving coefficients (0.74) than medium (0.44) and small (0.31) countries. In order to test country size both gross domestic product and population are tested for threshold effects.

Feldstein and Horioka (1980) hypothesize a lower correlation would emerge for more open countries. They interacted openness, measured as the sum of exports plus imports as a proportion of gross domestic product, with savings rates. If saving and investment regressions reflect capital mobility, countries that are more open should have a lower saving coefficient. Feldstein and Horioka find little evidence supporting this hypothesis. Separately controlling for size and openness Oskooee and Chakrabarti (2007) test saving and investment for cointegration in a recently developed heterogeneous panel framework. They find strong evidence in favor of country size and the trade openness hypothesis. AmirKhalkhali and Dar (2007) use a generalized least squares random coefficient error correction model on a panel of countries to test for different effects. Overall they find no evidence of a relationship between a lower saving coefficient with higher trade openness and greater capital mobility.

Previous research focuses mostly on trade openness measured as the sum of exports and imports as a proportion of gross domestic product or grouping countries by a measure relating to a discrete capital openness index. Both methods fail to account for actual financial investment. In order to control for changes in capital controls and financial investment an appropriate measure of financial openness needs to be tested. Lane and Milesi-Ferretti (2006) accumulate data measuring international transactions. Their data varies over time and shows the effects of actual investment by measuring financial openness as total foreign assets plus total foreign liabilities as a proportion of gross domestic product. This will also test the effects of a reduction in capital controls following the ending of the fixed exchange period.

In addition to trade openness, financial openness, and country size I am also interested in testing how the relationship changes by household demographics. Domestic saving is the sum of all individual household and government decisions. Aggregate household savings will be a function of age dependency, thus in order to properly model household savings, variables controlling for age dependency are included. Modeling the households decision making process is difficult, but evidence suggests countries with higher dependency ratios are less likely to run current account deficits. Herbertsson and Zoega (1999) find countries with a large percentage of working age individuals have larger amounts of saving. Countries with lower dependency rates can use saving to finance domestic or international investment, the latter leading to a change in the countries current account balance and likely the savings coefficient. Conversely, countries with higher dependency ratios are going to have lower levels of saving which could be reinvested into the domestic country, but these countries could turn to international sources for added capital. Countries with higher dependency rates generally have larger burdens due to retirement demands. Furthermore countries with a large percentage of retirees may face liquidity constraints. Instead of investing overseas excess saving is consumed by the retired adults.

Herwartz and Xu (2007) find a negative correlation between the age dependency ratio and coefficient on saving: the smaller fraction of working age adults is correlated with a lower savings coefficient. The theory of consumption smoothing suggests that agents attempt to smooth consumption over their lifetime. Income is not a constant flow, young agents are forced to borrow, working age agents will pay back previous loans and save for retirement, and retired agents will consume savings. If a country has a larger percentage of young agents it is likely the country will a run a current account deficit. The same logic applies to an older population as they will be consuming their previous saving. The net effect of a large percent of working age adults is unclear.

Countries that are most likely to have saving coefficients near zero will be small, relatively open, have lower levels of income per capita, and have a large proportion of dependents. The question becomes how should these effects be modeled within the saving-investment context and related to the current account.

Methodology

In order to test the saving-investment relationship I follow methods developed by Pesaran, Shin, and Smith (1997, 1999) and Hansen (1999). I first take advantage of the dynamic panel estimators to measure the short and long-run relationship. Next I use Hansen's threshold approach to the long-run relationship for threshold effects in trade openness and country size. In both instances I control for the structural breaks found in the previous chapter. In the latter method, the regressions are divided into regimes if the threshold variables are greater or less than the threshold values. When controlling for threshold effects in trade openness and country size the savings coefficient to be statistically insignificant. The dynamic panel estimators shows the savings coefficient is lower after the structural breaks are removed from the data.

MG and PMG Estimators

The starting point for our analysis begins with a basic short-run dynamic saving-investment regression. In order to capture short-run capital mobility I estimate the following regression:

$$\Delta i_{it} = \alpha + \beta \Delta s_{it} + \epsilon_{it} \tag{V.1}$$

where the number of countries $i = 1, 2, ..., N$; the number of periods $t = 1, 2, ..., T$; $i_t = I/Y$; and $s_t = S/Y$. Equation V.1 is an appropriate specification to measure the short-run dynamics, but ignores the long-run relationship. If β is small (large) then capital is mobile (immobile). Equation V.1 is an appropriate specification if saving and investment rates do not have a long-run relationship.

The first extension to equation V.1 is to jointly model the short-run and long-run relationships between saving and investment rates. Assume the long-run relationship between saving and investment rates:

$$i_{it} = \theta_{0t} + \theta_{1t} s_{it} + \mu_i + \epsilon_{it} \tag{V.2}$$

where μ_i represents a country specific term. The autoregressive distributive lag dynamic panel specification of equation V.2 is the following ARDL(1, 1) model:

$$i_{it} = \beta_{10i} s_{it} + \beta_{11i} s_{i,t-1} + \lambda_i i_{i,t-1} + \mu_i + \epsilon_{it}. \tag{V.3}$$

The error correction reparameterization of equation V.3 is:

$$\Delta i_{it} = \alpha_i + \gamma_i (i_{i,t-1} - \theta_i s_{i,t-1}) + \beta_i \Delta s_{i,t-1} + \epsilon_{it} \tag{V.4}$$

where $\alpha_i = \mu_i$, $\theta_i = (\delta_{11i} + \delta_{10i})/(1 - \lambda_i)$, and $\beta_i = \delta_{10i}$. To be consistent with previous sections I assume $\theta_i = 1$, countries are constraint by an intertemporal budget constraint in the long-run. Similar to the single country analysis γ_i measures the error correction speed of adjustment and β_i represents the short-run dynamics. Capital mobility exists if the error correction term, γ_i, is insignificant from zero or a long-run relationship is significant but β_i is small.

There are a couple of different methods to estimate equation V.4. The first approach is to use a dynamic fixed effects (DFE) approach. Under the DFE approach the time-series data are pooled together allowing only the intercepts to differ across groups. The DFE estimator assumes common slope coefficients; if the slope coefficients are not identical, the DFE approach could produce inconsistent and potential misleading results. One correction to the DFE model is the mean group estimator proposed by Pesaran and Smith (1995). The MG estimator fits the model separately for each country, and a simple arithmetic average of the coefficient is calculated. Within the MG estimator the intercepts, slope coefficients, and error variances are allowed to differ across groups. The mean group estimator has been used extensively by Coakley et al., (1996) in the context of saving-investment regressions. The test is robust of I(0) and I(1) estimators, making it a nature candidate for testing the long-run relationship.

More recently Pesaran, Shin, and Smith (1997) have proposed a pooled mean group estimator. The PMG estimator can be seen as a combination of the DFE and MG estimators. The PMG allows the intercept, short-run coefficient, and error variances to differ across countries similar to the MG estimator, but constrains the long-run coefficients to be equal across groups similar to the DFE estimator. Pesaran, Shin, and Smith (1999) have proposed a maximum likelihood method to estimate the parameters.[1] All three estimators are used to measure the effects of removing structural breaks on the savings coefficient.

Threshold Effects

Following Hansen (1999) the threshold effects are tested in a fixed effect framework. Both saving and investment rates are taken as mean deviations. Using mean deviations has the same effect as including dummy variables to account for country heterogeneity. Ho (2003) applies a similar model to test country size. Previous studies have arbitrarily selected threshold break points instead of estimating statistically significant breaks from the data.

The first step is to determine the appropriate number of thresholds (or regime switches) for each variable. First estimate the restricted model, i.e. no threshold effect:

$$i_{it} = \alpha_i + \beta s_{it} + e_{it} \tag{V.5}$$

where $i = 1, ..., N$ and $t = 1, ..., T$. Where variables i_{it} and s_{it} are taken as mean deviations controlling for mean shifts. The next step is to find the optimal threshold value by estimating the following equation:

$$i_{it} = \alpha_i + \beta_1 s_{it} I(q_{it} \leq \gamma) + \beta_2 s_{it} I(q_{it} > \gamma) + e_{it} \tag{V.6}$$

where q_{it} is a scalar threshold variable and $I(\cdot)$ is the indicator function that takes a value of one when the threshold condition in the bracket is satisfied, zero otherwise.

[1]The author is grateful that Edward Blackburn and Mark Frank have shared their Stata routine for the maximum likelihood estimation for the PMG estimator.

The error term is assumed to be independent and identically distributed with mean zero and finite variance σ^2.

Instead of searching continuously over all possible threshold values the search is limited to the following grid {10%, 10.25%, 10.5%, 10.75%, 11%,..., 90%}. The bottom and top tenth percentiles are omitted during the grid search. The optimal threshold value minimizes the sum of squared errors. After selecting the optimal threshold value it is important to determine if a threshold effect is statistically significant. The null hypothesis of no threshold effect is

$$H_0 : \beta_1 = \beta_2.$$

$\beta_1 = \beta_2$ is tested by a likelihood ratio test. Under the null hypothesis γ is not identified thus Hansen suggests a bootstrapping procedure to simulate the asymptotic distribution of the likelihood ratio test. The likelihood ratio test is:

$$F_1 = \frac{S_0 - S_1(\hat{\gamma})}{\hat{\sigma^2}} \tag{V.7}$$

where $\hat{\sigma^2} = \frac{1}{n(T-1)} S_1(\hat{\gamma})$, S_0 are the sum of squared errors from the restricted regression and $S_1(\hat{\gamma})$ is the sum of squared errors from the unrestricted regression. The null hypothesis is rejected for large values of the likelihood ratio. Once the single threshold is estimated the process of estimation extends easily to models with two and three thresholds.

To determine the second threshold break the following model is estimated:

$$i_{it} = \alpha_i + \beta_1 s_{it} I(q_{it} \leq \gamma_1) + \beta_2 s_{it} I(\gamma_1 < q_{it} \leq \gamma_2) + \beta_3 s_{it} I(\gamma_2 < q_{it}) + e_{it} \tag{V.8}$$

Similar to equation (V.6), equation (V.8) is estimated using a grid search. The second threshold is selected to minimize the joint sum of squares taking the first threshold as given. In order to ensure a large enough sample within each threshold the second break point is restricted to be at least 10 percentile points larger or smaller than the first threshold value.

Instead of testing for the existence of a threshold the likelihood ratio test is

$$H_0 : \beta_1 = \beta_2 = \beta_3.$$

Bai (1997) shows that the second threshold is asymptotically efficient but the first threshold is not. Bai suggests a refinement estimator to fix the second threshold and then re-estimate the first threshold. If a second threshold is found to be statistically significant then a third regime threshold is estimated. The saving coefficient is unique for each regime. Using a bootstrapping procedure following Hansen (1996) is used to construct asymptotically valid p-values and critical values for the likelihood ratio test. One thousand bootstrap replications are used for each threshold variable.

Results

The data set is balanced with 22 countries starting in 1950 through 2004. The results are presented for the dynamic estimators and threshold effects.

MG and PMG Estimators

The results for the DFE, MG, and PMG estimators are presented in tables 5.1 and 5.2. The results for a basic dynamic model that regresses a change in savings rates on investment rates are also presented. Table 5.1 presents the results for the original data set and controlling for structural breaks. The savings coefficient is significant lower for all estimators, after controlling for structural breaks. In addition to estimating the short-run relationship the long-run results are also presented. The coefficient measuring the long-run relationship, γ, increases after controlling for the structural breaks. Failure to control for structural breaks bias the short-run coefficient toward unity and suggests countries can sustain external imbalances longer then what is realistic. Without controlling for structural breaks, a current account deficit of 4% will result in a 1% reduction in investment rates. After 6 years the current account deficit be reduced by approximately 80%. After removing significant structural breaks from the data the long-run adjustment process occurs more quickly. A current account deficit of 4% will result in a 2.5 - 3% reduction in investment rates. The current account deficit will be reduced by 80% in less then 2 years.

Next the results are presented when the demeaned data are tested across time periods. The savings-investment regressions are tested from 1950-1972, 1973-1991, and 1992-2004. These time periods were commonly found to exhibit significant structural breaks. Table 5.2 presents the results for the four dynamic models estimated for each time period. Each estimator presents a significantly lower savings coefficient into the 21st century. The lowest coefficient appears for the later time period in the simple dynamic model. In addition to a declining savings coefficient, the adjustment coefficient, γ, also decreases overtime. This is consistent with countries having the ability to sustain current account imbalances for a larger number of years. The lower savings coefficient combined with sustaining external imbalances presents overwhelming evidence in favor of increasing capital mobility.

Threshold Effects

The threshold effects procedure is tested with data for 22 OECD countries from 1950-2004. Trade openness is the sum of exports plus imports relative to gross domestic product. Country size is based on the gross domestic product relative to the mean of all countries, by year. Age dependency represents the fraction of the population under the age of 16 and over 65, the variable is taken from the World Bank. The financial openness variable is the sum of total assets and total liabilities relative to gross domestic product from Lane and Milesi-Ferretti (2006). Both savings and investment rates are demeaned to control for exogenous structural breaks.

Tables 5.3, 5.4, and 5.5 presents the summary statistics, test statistics, and regressions results for the threshold effects model outlined above. P-values are calculated from a bootstrapping procedure as the number of times the simulated F-statistic exceeds the actual F-statistic. As expected there are a number of statistically significant thresholds. Trade openness, country size, GDP per capita, and age dependency display evidence of one significant threshold. Trade Balance has two significant thresholds, and financial openness strongly rejects threshold effects.

Table 5.5 presents the results for the panel regressions controlling for each threshold regime, report the threshold value for each variable, saving coefficients, and standard errors for both regressions. Combining the above tables with table 5.3 gives an idea where each threshold lies relative to the minimum, maximum, median, 25th and 75th percentiles. The second column in the regression tables shows the threshold parameter. Without controlling for thresholds the savings coefficient is 0.397. This estimate is much lower than previously estimated models from controlling for structural breaks. The savings coefficient is insignificant from zero for countries with high degrees of trade openness. The coefficient decreases for countries with large trade deficits, small countries, and lower levels of dependents. These results are consistent with our expectations about capital mobility. Countries with large trade deficits by definition are going to have a high degree of capital mobility. Small, open countries are will resort to external funding sources. Lastly, countries with lower measures of dependents will likely seek out international investments.

The savings coefficient increases for relatively closed countries, small trade imbalances, and large countries. These results are again consistent with other measures of capital mobility. It is also useful to compare the threshold values with table 5.3. This provides an overview of the location of each threshold. For example the threshold value of trade openness is 0.755 which corresponds with the 75th percentile. The open country effect is only significant for a small fraction of the countries. Similarly, the lower threshold for trade balance lies below the 25th percentile but the upper threshold is between the median and 75th percentile. Conversely, the measure of country size lies between the median and 75th percentile, but the age dependency threshold is slightly above the 75th percentile.

The results are consistent with different degrees of capital mobility, but the thresholds are often found to represent a small fraction of the sample. For most cases the savings coefficient is significant around the 0.35 to 0.50 value. By no means does the result provide evidence against capital mobility. Countries across all parameter values display some degree of capital mobility.

Conclusion

In this chapter I presented results that test the savings-investment relationship using recently developed dynamic panel techniques and non-dynamic panel threshold effects. I show that controlling for heterogenous structural breaks from the univariate tests significantly lower the savings coefficient for a dynamic fixed effects, mean group, and pooled mean group estimator. In addition to lower the savings coefficient the long-run adjustment parameter increased, countries have less ability to run an external imbalance. Continuing the analysis using the demeaned data will apply the same estimators to samples split by time periods. The savings coefficient significantly lowers over time and countries have greater ability to sustain external imbalances. The long-run adjustment mechanism has decreased over time. These results confirm capital mobility has increased into the 21st century.

Next I applied the demeaned data to the non-dynamic threshold procedure developed by Hansen (1999). Trade openness, country size, trade balance, income per capita, and age dependency have significant thresholds. The savings coefficient is smallest for relatively open and small countries and largest for countries that are closed, have a small trade imbalance, and are large in size. These results are consistent with other authors using dynamic panel estimators to measure the relationship.

There are a number of extensions following the work presented here. First it is valuable to test the relationship for developing countries. Next I would like to develop a more complete data set that allows for testing additional threshold variables across a larger sample. Finally, a more technical extension would be to develop an estimator that allows for testing threshold effects using a dynamic model. For now one avenue would be to incorporate the thresholds in a country analysis using a threshold autoregression approach.

Table 5.1. Entire Sample

	Fixed Effects		Dynamic FE		Mean Group		Pooled MG	
Variable	Levels	Demeaned	Levels	Demeaned	Levels	Demeaned	Levels	Demeaned
β	0.598	0.437	0.586	0.422	0.726	0.521	0.709	0.479
(S.E.)	0.094	0.085	0.103	0.078	0.082	0.055	0.531	0.554
γ			-0.209	-0.603	-0.333	-0.595	-0.299	-0.565
(S.E.)			0.051	0.034	0.053	0.033	0.053	0.030
α	-0.025	0.011	1.256	0.004	-0.356	0.007	0.425	0.001
(S.E.)	0.009	0.003	0.980	0.002	0.861	0.012	0.162	0.011

Table 5.2. Pre and Post Bretton Woods

	Fixed Effects			Dynamic FE			Mean Group			Pooled MG		
Variable	1950-72	73-91	92-04	50-72	73-91	92-04	50-72	73-91	92-04	50-72	73-91	92-04
β	0.461	0.452	0.272	0.466	0.404	0.342	0.590	0.557	0.497	0.569	0.539	0.463
(S.E.)	0.114	0.123	0.131	0.107	0.117	0.126	0.063	0.109	0.112	0.065	0.087	0.077
γ				-0.763	-0.584	-0.443	-0.749	-0.659	-0.507	-0.699	-0.553	-0.351
(S.E.)				0.063	0.062	0.095	0.044	0.052	0.062	0.049	0.038	0.058
α	-0.044	0.041	0.083	0.013	0.121	-0.098	-0.004	0.087	-0.213	-0.005	0.118	-0.114
(S.E.)	0.009	0.009	0.018	0.013	0.013	0.041	0.063	0.052	0.119	0.055	0.053	0.111

Table 5.3. Summary Statistics

Variable	N	Min	25%	Median	75%	Max
Trade Openness	1188	0.031	0.354	0.517	0.700	1.842
Financial Openness	770	0.187	0.613	1.114	2.049	18.800
Trade Balance	1188	-21.461	-2.148	-0.305	1.437	17.334
Country Size	1188	0.009	0.464	0.888	2.627	33.352
Income per Capita	1188	0.392	1.731	2.311	2.661	4.088
Age Dependency	990	0.433	0.495	0.539	0.587	0.880

Table 5.4. Tests for Threshold Effects

	Breaks	F-Stat	P-Values	Critical Values
Trade Open	Single	22.34	.008	(21.5, 13.1, 9.4)
	Double	5.42	.364	(26.6, 16.4, 12.6)
	Triple	6.37	.474	(39.9, 20.9, 16.8)
Financial Open	Single	1.67	.614	(19.4, 11.2, 8.1)
	Double	0.28	.962	(23.9, 14.7, 10.6)
	Triple			
Trade Balance	Single	32.54	.003	(27.5, 14.2, 10.9)
	Double	23.25	.036	(35.2, 20.1, 14.4)
	Triple	9.60	.280	(44.3, 22.9, 16.5)
Country Size	Single	18.00	.001	(17.2, 9.4, 6.6)
	Double	8.71	.212	(27.6, 17.1, 12.8)
	Triple	17.75	.100	(36.2, 22.6, 17.6)
GDP Per Capita	Single	12.42	.028	(16.9, 9.9, 7.7)
	Double	2.84	.576	(25.5, 13.2, 10.7)
	Triple	3.79	.620	(26.2, 18.5, 14.9)
Age Dependency	Single	9.81	.074	(19.6, 12.0, 9.1)
	Double	7.17	.248	(30.4, 14.4, 11.4)
	Triple	4.26	.608	(34.1, 20.0, 13.2)

Critical values obtained from 500 bootstrap replications

Table 5.5. Regression Estimates with Threshold Estimates (All Countries)

Threshold Variable	Regressors	β_i	S.E.	R^2
Saving Rates	s_{it}	.397	.033	.109
Trade Openness	$s_{it}I(x_{it} > .755)$	.077	.075	.126
	$s_{it}I(x_{it} \leq .755)$	.478	.037	
Financial Openness	$s_{it}I(x_{it} > 1.25)$	.353	.053	.096
	$s_{it}I(x_{it} \leq 1.25)$	.387	.067	
Trade Balance	$s_{it}I(x_{it} > .427)$	.443	.058	.150
	$s_{it}I(-2.846 < x_{it} \leq .427)$	.618	.055	
	$s_{it}I(x_{it} \leq -2.846)$	.296	.057	
Country Size	$s_{it}I(x_{it} > 1.310)$	.652	.072	.122
	$s_{it}I(x_{it} \leq 1.310)$	.336	.037	
Income per Capita	$s_{it}I(x_{it} > 2.488)$	.664	.078	.118
	$s_{it}I(x_{it} \leq 2.488)$	.343	.036	
Age Dependency	$s_{it}I(x_{it} > .608)$	.476	.042	.130
	$s_{it}I(x_{it} \leq .608)$	.247	.069	

CHAPTER VI

CONCLUSION

This dissertation consists of five chapters modeling savings and investment rates to measure capital mobility and current account dynamics for a sample of 24 OECD countries. The first chapter introduces the Feldstein-Horioka Puzzle. The second chapter provides an overview of savings and investment rates by comparing estimates across three regressions commonly used in the literature. These models include: the tradition Feldstein-Horioka regression, an error correction regression, and an autoregressive distributive lag model. Lastly, general stability tests are conducted and all the models display country specific evidence of being unstable. The third chapter presents results that overwhelmingly reject non-stationarity using more powerful unit root tests and controlling for structural breaks. Previous research has consistently found non-stationary savings and investment rates while each variable was expressed relative to gross domestic product. This goes against the common belief of a constant growth path for investment, consumption, and output argued by real business cycle economists. This chapter extends the literature by incorporating the use of a Dickey-Fuller generalized least squares unit root tests and structural break tests following Perron and Vogelsang that control for single and double mean shifts.

The fourth chapter presents evidence that the saving-investment correlation is significantly reduced after controlling for exogenous breaks. These breaks are often related to country specific and global business cycle shocks. Removing the structural breaks also allows for a more accurate representation of the short-run dynamics which are used to measure the current account adjustment process. Finally, the fifth chapter shows that the structural break hypothesis is consistent in a panel framework. This chapter compares estimates between the mean differenced and original series using four dynamic panel models which include a simple short-run fixed effects regression, pooled mean group estimator, mean group estimator, and dynamic fixed effects. Each model is estimated in three distinct time periods: 1950-1972, 1973-1990, and 1990-2004. Additionally, the application of a threshold effects procedure explains the remaining correlation. These results are consistent with other researchers in which small, open economies have a weaker relationship between savings and investment rates. Thus, the overall implication of this work is saving and investment rates can be used to measure capital mobility after appropriately testing the variables for stationarity and structural breaks and controlling for additional variables correlated with capital mobility.

Given all of the above, some extensions for future work naturally follow. The first extension from my dissertation will be to apply the results to a larger set of countries. Particular sets of countries include those from Asian, Latin American, and Eastern European regions. When comparing these countries to the more developed set explored in my dissertation the external adjustment process is likely to be different, the nature of shocks to both variables will include political events, exchange rate crises, and capital reversals. After estimating the results for developing countries the next logical step is to more formally test the underlying causes of the breaks and the probability of a break occurring in either variable. Key variables to include are government deficits, foreign reserve accumulation, exchange rate regimes, age demographics, policy changes, money growth, GDP growth rates, and openness measures. These variables will hopefully help predict when a sudden shift is about to occur.

Another extension is to test the effects of controlling for univariate breaks prior to the modeling the multivariate model. The saving-investment literature has failed to control for structural break and proceeded into testing the cointegration relationship. A concerning issue is that a bias may result from the failure to control for structural breaks in a univariate series when applying cointegration tests. I am planning on testing the power of cointegration tests when the univariate series have known structural breaks that may occur simultaneously or within a specified time period. In order to conduct this test a basic Monte Carlo simulation will be implemented. If the breaks are independent then cointegration tests will be biased toward the failure of rejecting a long-run relationship. Furthermore this will provide a controlled environment for testing the effects of removing structural breaks in a simple bivariate model. This approach will place added emphasis on the importance of being able to understanding the underlying variables causing the break to occur and the timing of each break. This leads the third extension.

The third extension will use disaggregated data to gather more information to understand the cause of each break. In the case of saving rates it will be useful to separate savings into three main components, corporate, household, and public savings. If the shift in savings is caused from a change in public savings then it should be independent of capital mobility. Breaking up investment similarly will also help explain the relationship. Investment rates will be split up into inventories, residential investment, and nonresidential investment. Shifts in inventories and residential investment are likely to be independent of capital mobility.

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