Finance and Growth:
An Analysis of Causality for Cointegrated Panels

by

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Abstract

The relationship between finance and economic growth has been a source of research interest over the past century. This paper applies a panel cointegration based test for long-run causality from Pedroni and Canning (2008) to the finance-growth field for the first time. The methodologies used are robust to endogeneity, omitted variable bias, and reverse causality, while allowing for heterogeneous long-run cointegrating relationships and short-run dynamics across panel members. An analysis of three bivariate cointegrating relationships between proxies for the size of a financial system and GDP per capita reveals that bi-directional long-run causality exists pervasively among panel members. This finding confirms a diverse set of recent empirical work in the finance-growth field and contributes a new long-run causal perspective. In addition, a test for the sign of this causal relationship relative to a growth maximizing point indicates that panel members are pervasively overinvested in the size of financial systems.

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I. Introduction

Finance is often broadly associated with functional roles including the pooling of savings and reallocation of capital, but the extent to which finance leads to economic growth remains uncertain. Although research in the finance-growth field has expanded from the landmark work on creative destruction by Joseph Schumpeter in 1911 to empirical studies today, a conclusive causal linkage between finance and growth is still in dispute. In an attempt to address a core area of disagreement in the field, this paper investigates the long-run causal relationship between the size of a financial system and economic growth for a panel of 23 countries over a 48 year time frame. Although definitions of finance take a variety of forms in the empirical literature, this study includes variables measuring total bank deposits, total financial system deposits, and bank credit extended to the private sector. These variables serve as proxies for the size of a financial system and mimic the various functions of finance. For the purposes of this paper, the functions of finance follow from Levine (1997) and include the allocation of capital, monitoring of credit, amelioration of risk, pooling of savings, and facilitation of exchange.

The empirical evaluation in this research utilizes a methodology new to the finance-growth field, following the panel cointegration work of Pedroni (2000) and the study of long-run causality in cointegrated panels done by Pedroni and Canning (2008). Through an analysis of three distinct panels of bivariate cointegrating relationships between proxies for the size of a financial sector and economic growth, this paper intends to establish proof of bi-directional long-run causality. The empirical methodology also allows for an evaluation of the direction of such causal relationships. This result indicates whether an economy is overinvested or underinvested in the size of the financial sector relative to a growth maximizing point.

The benefits of cointegrated panel approaches include adding robustness to many of the issues plaguing standard regressions in the field, such as omitted variable bias, endogeneity reverse causality, and simultaneity. In addition, this methodology models each cointegrating relationship separately and allows for heterogeneity in the member specific long-run relationship and short-run adjustment dynamics. In order to deal with panel wide cross-sectional dependence, common time effects have been removed. The methodology utilizes the cross-sectional element to supplement confidence limited by the short time span of the available data for individual countries.

The principle goals of this empirical investigation are twofold. First, this research tests the hypothesis that bi-directional causality exists between the size of a financial sector and economic growth as measured by gross domestic product per capita. A consensus supports the claim that the growth of an economy leads to an expansion in the size of the financial sector. The idea that the expanding size of the financial sector drives economic growth, however, has been more controversial. Although a large body of work has explored the theoretical mechanisms by which finance may promote growth, and recent empirical studies support the idea that finance may indeed cause growth, the causal link has remained uncertain. Contrary to the work of Robinson (1952) and contemporaries, the model developed and used in this research implies that finance does not simply follow the development of new industry within an economy, but rather causes growth. Although some proxies for finance may simply drift in parallel with economic growth over time, the empirical results in this paper indicate that several variables representing the size of a financial system cause growth. Second, this paper investigates the sign of causal relationships relative to a growth maximizing point. The results can help inform decisions regarding whether current resource allocations towards the size of the financial system are above, below, or at the maximizing level. For example, if a variable for the size of finance is found to have a long-run causal relationship, but a negative causal sign, this result implies that the size of finance is crowding out some other type of investment which would produce a higher return to economic growth.

Building upon the empirical results, the original 23 country panel data set is divided into higher and lower income cohorts to ascertain if the original results are impacted by varying levels of economic development. While bi-directional causality holds for both the full panel and a higher income cohort, the lower income panel lacks proof that the size of the financial sector causes economic growth. The tests for the signs of these causal relationships indicate that the full and high income panel members are overinvested in the size of finance relative to other macro investments in relation to a growth maximizing point.

The remainder of the paper proceeds as follows. Section II places the investigation in a larger context by examining the historical and contemporary literature in the field. First, a basic Schumpeterian production function expressing the relationship between the size of the financial system and growth is constructed. The discussion continues in section II.B with an overview of the functions of finance and the transmission mechanisms by which finance may cause economic growth. Following a review of contemporary findings in the field, section II.C includes an overview of the various empirical methodologies previously employed to highlight the specific contributions of this investigation and to define the advantages of a non-stationary panel approach. Section III provides a comprehensive overview of the data and methodology utilized in this paper. Much of this discussion follows from the work of Pedroni and Canning (2008) and seeks to clarify the empirical tools utilized to uncover the cointegrating relationships, establish causality, and reveal the sign of this causal relationship. Section IV presents the empirical results. Finally, section V presents concluding thoughts on the empirical results. A number of appendices follow this text to extend upon mathematical derivations, present a number of supplemental tables, and to display the RATS computer code utilized to obtain empirical results.

II. Literature Review

The existing literature in the field demonstrates the breadth of empirical techniques employed to examine the relationship between finance and growth. This section begins with a basic Schumpeterian production function to explore the economic relationship between finance and growth in the context of technological innovation. Next, a discussion of the principle functions of finance and the transmission mechanisms by which finance causes growth develops the theoretical connections underlying the empirical results. Finally, a more traditional review will present the key findings from existing literature in the field. This section of the paper highlights contemporary empirical results and overviews the various methodologies previously utilized to place this paper in a larger context. Despite a tremendous range of empirical and theoretical approaches used in evaluating the relationship between finance and growth, a vast majority of recent work has confirmed the existence of a connection.

II.A. A Finance-Growth Production Function

This section constructs a basic Schumpeterian production function relating the functions of a financial system to economic growth. While this production function will demonstrate some of the linkages between the size of a financial system with several other critical systemic qualities and growth, it is not intended to represent a comprehensive theoretical framework. Rather, this piece helps to facilitate discussion of transmission mechanisms and the concept of growth maximization in relation to causality results. The model presents the supply side and an analog to the capital accumulation equation while omitting the demand side. In this sense, there is no final equilibrium for which to solve. The empirical model remains more nuanced than the theoretical model and allows for heterogeneous adjustment dynamics and long-run cointegrating relationships along with all other features as described in the methodology section.

The production function is informed by the work of Aghion and Howitt (1998) which draws inspiration from the original Schumpeterian model. The simplified version of these models has been altered in this paper to include a functional relationship with a financial sector and has been influenced by Laeven, Levine, and Michalopoulos' (2009) research. Schumpeter's (1911) work explores the role of the intersection between technology and economics in driving innovation. In Schumpeter's model, individual entrepreneurs actively screen ideas for innovation and theoretically pursue ideas which will not only improve consumption of their own product, but will also increase the technological productivity of the economy as a whole. The interplay between technology and economics drives growth endogenously. The modified production function constructed in this section also includes a financial sector which provides the financial capital necessary to pursue innovation through research and investment.

Before beginning a more technical construction, a brief list of general assumptions provides the theoretical inspiration for pursuing a Schumpeterian model. The hypothesis of bi-directional causality between finance and growth which generates permanent long-run effects suggests an endogenous rather than an exogenous growth model. In the endogenous model, individual shocks can exert long-run changes. Extending Schumpeter's theory that technology and economics intersect to produce innovation, this paper claims that innovation requires some degree of finance in the creative and developmental process. In this model, the supply, cost, and quality of finance may all affect the incentives for innovation and degree of capital accumulation.

The production function is constructed for the case of a single country. For any given country, aggregate gross domestic product can be defined as:

$$(1) \qquad y_t = A_t \sum_{n=1}^{N} x_{nt}^{\alpha}$$

Output for any time period t is defined by total factor productivity A_t and the summation of inputs of intermediate goods and services x where $0<\alpha<1$ and N represents the total number of intermediate goods.

In this given economy, the fixed quantity of labor can either participate in the creation of intermediate goods or in pursuing research:

$$(2) \qquad L_t = g_t + z_t$$

Here, g_t represents the quantity of labor utilized in creating intermediate goods and z_t the portion focused on research. With z_t laborers pursuing research, innovations randomly arrive at a rate of λz_t whereby the rate of innovation increases as z_t increases. Employees of financial institutions introduced later as v_t constitute a subset of laborers drawing from both g_t and z_t.

With a basic economy in place, a financial system is now introduced following from the work of Aghion and Howitt (2001), King and Levine (1993a), and Berthelemy and Varoudakis (1996). Banks lend out funds to perspective borrowers at a premium over the real interest rate in order to make a profit. The borrowing rate R_t is then defined as:

$$(3) \qquad R_t = (1 + i_t) r_t$$

Variable r_t represents the real interest rate on savings deposited in the bank and i_t accounts for the endogenous cost of intermediation. Although the premium ensures a profit for individual firms, later discussion presents the various services financial institutions perform which create further costs for financial institutions. R_t defines the cost of financial credit extended at a given time. The value of R_t is common to financial system lenders because of competition. For the purposes of this model, the cost of finance R_t represents the aggregate function for a given country's entire financial sector at a given time. Also, the development of the financial sector may lower the costs of intermediation i_t over time. By lowering information and transaction costs and providing more secure risk amelioration, for example, a financial system can reduce the premium required for credit extension.

Banks lend out a supply of credit C_t defined as:

(4) $$C_t = f(v_t)S_t(r_t)$$

The supply C_t is constructed by considering both the quantity and quality of financial intermediation v_t approximated as employees of financial institutions, as well as the quantity of deposits S_t which represent the funds available to lend. The quantity of deposits maintains a positive relationship with the real rate of interest. For the purposes of the empirical investigation developed in this paper, the size of the financial sector can be defined by proxies such as total credit extended C_t or as total deposits in a financial system represented by S_t. Total deposited savings measures the potential size of funds extended. Total credit extended, on the other hand, also accounts for unpredictable and inconsistent dynamic factors such as the quality of credit extended and the unique lending practices in a given country at a given time. By this argument, the variable v_t not only serves as the quantity of financial sector employees, but also plays a role in defining effective credit extension. For the purposes of this simplified model, the "quality" of financial intermediation will be left to theoretical consideration and discussed in the context of final results. Individual depository and lending institutions are free to enter and leave this market within the country specific legal bounds unspecified in this model.

The assumptions and functions noted are combined to create the modified, reduced form endogenous growth model:

$$(5) \qquad y_t = A_t \sum_{n=1}^{N} x_{nt}^{\alpha}(C_t, R_t)$$

where $\frac{\partial x_t^{\alpha}}{\partial C_t} > 0$ and $\frac{\partial x_t^{\alpha}}{\partial R_t} < 0$.

Here, total factor productivity and the summation of intermediate outputs as a function of the "cost" of finance R_t and amount of finance available C_t drive total output. The model assumes that discrete producers of intermediate products require some degree of external finance to pay for innovation and operations. The development of new products and innovations is therefore dependent on the availability and cost of credit. By increasing credit available C_t or decreasing the cost of credit R_t, the quantity and quality of x_t increases by innovation. Variable Δx_t represents an abstract proxy for innovation of intermediate products. Furthermore:

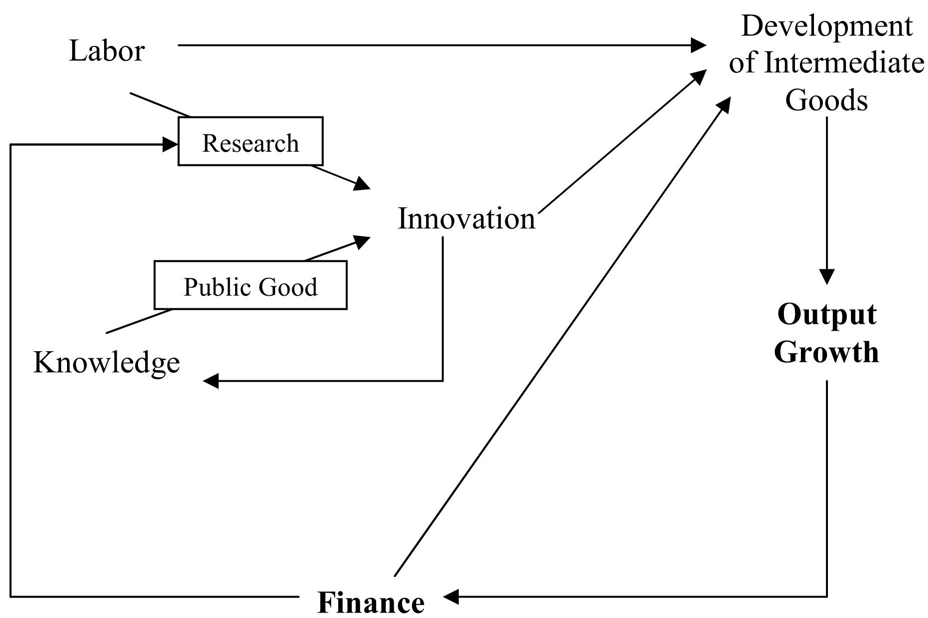
$$(6) \qquad \Delta A_t = A_t(\Delta x_t)$$

Here, innovations in intermediate products can be said to positively impact total factor productivity in the long run by the cumulative use of these new and more efficient products. Simultaneously, increases in total output y_t can produce a number of direct and indirect feedback effects. For example, by increasing total output, saving may increase which will increase the availability of credit. In addition, the expansion of the economy will likely drive the expansion of financial sector employment incorporated in v_t which will further drive credit expansion. As a result of this and other changes, increases in output may also lower the premium i_t incorporated in the cost of credit by lowering transaction and informational costs by scale of operation or by a number of other factors. A decrease in the cost of credit allows for greater investment in innovation, potentially leading to further expansion of total factor productivity and output.

This production function can also be related to the idea of growth maximization. In the dynamics of the model, there is some size of the financial system which maximizes the rate of growth in a given economy. If too many resources are directed to creating the financial system size, an economy is below the maximized growth level. This indicates that the size of finance is crowding out another macro investment which presents higher returns to growth. To the contrary, if the resources directed to developing finance are too low, then economic growth falls from a maximized level, indicating that the size of the financial system would have presented greater returns to growth than some other macro investments. The sign test of causality presented in the final results of this paper will investigate the position on this spectrum, determining whether the aggregate investment in finance relative to growth is above, below, or at a maximizing level.

Returning to the model, a modified version of a diagram originally presented in Aghion and Howitt (1998) helps to illustrate the cycle effect created by the relationships between finance, innovation, and growth, as depicted in Diagram 1.

Diagram 1: The Simplified Finance-Growth Cycle



The modified version of the model highlights the role of finance in facilitating the process of research and in the development of intermediate products. Returns to total factor productivity A_t for a country's economy as a whole are also reflected in the feedback from innovation to knowledge.

II.B. The Functions of Finance

The Schumpeterian production function helps illustrate the principle functions of finance and the transmission mechanisms by which these features may cause growth. Some functions have already been noted in constructing this model, but a more comprehensive treatment following from the work of Levine and Demirgüc-Kunt (2008b), Levine (2005) and Levine (1997) demonstrates the theoretical causal link between finance and growth. The five principle functions of finance outlined by Levine (1997) highlight the intended and indirect roles a financial sector may have in a given economy. These functions include allocating credit, monitoring the use of credit, risk amelioration, pooling of savings, and facilitating exchange. In reality, these features may have a positive or negative impact on growth maximization in a given country, and all possible effects will be critical when interpreting causality results.

The first function of finance is to allocate credit. By gathering information in scale, financial intermediaries can more efficiently allocate resources by alleviating savers' concerns and redistributing credit to higher value uses. In a given economy without any form of financial system, enormous costs exist to firms and other economic actors in evaluating investment options. The assumption that transparent, available, and correct information exists for evaluation by these individual players underlies the very foundation of the Schumpeterian model. Individual actors face significant fixed costs in developing information and even after such an investment, smaller scale savers will have a limited amount of knowledge regarding a fraction of total investment opportunities. The establishment of a large scale depository institution may then drastically reduce the costs associated with information gathering and increase the availability of information to all players. In addition to increasing the rate of informational turnover, access to information may serve to accelerate the rate of growth as well by assisting in determining which investments are legitimate and will succeed in the long run. Levine and Demirgüc-Kunt (2007) support this theoretical function by explaining that finance may serve to equalize opportunity for all economic players regardless of previous resources by reducing the large fixed costs in obtaining information.

In addition to providing information, financial systems monitor capital use and enforce financial contracts. When financial institutions succeed in monitoring capital use, more savers are willing to participate in funding investments as they feel more secure in depositing their money. A larger depository base in an economy correspondingly increases the potential quantity of credit extended to borrowers. Successful monitoring also improves the efficiency by which capital is allocated by ensuring that borrowers use their resources in pursuing previously agreed upon goals. This practice demonstrates value maximizing behavior by lenders in dis-incentivizing wasteful behavior by borrowers. The country specific legal framework and financial regulation once again play an important role in this process. Only by allowing for reasonable protection of all savers and lenders, down to the small-scale saver, can a financial system achieve optimal efficiency in the allocation of resources. De la Fuente and Martin (1995) support the theoretical framework presented by Levine (1997) by finding that in undertaking the costly process of monitoring capital use, financial system actors improve overall credit allocation and positively impact economic growth.

Third, financial intermediaries allow for amelioration of both cross-sectional risk by spreading funds out across a variety of investment projects, and liquidity risk by maintaining some reserve funds. King and Levine (1993a) support the connection between minimizing cross-sectional risk and growth. Their work demonstrates that financial institutions display growth maximizing behavior by holding a balance between more risky innovative investments with higher returns and other lower risk investments. This process ties closely with the fourth function of finance, the efficient pooling of savings. By operating at scale, a financial system overcomes large transaction costs associated with the actual process of pooling savings as well as the informational costs associated with convincing savers that their money will be secure in the hands of another party. The larger depository base then facilitates the other financial functions previously discussed, including increasing the efficiency in the scale of investments and ameliorating risk, by diversifying across various opportunities. Specifically, a larger savings pool increases the potential scale of investments by non-financial sector firms, facilitating firm growth.

The final of Levine's five functions of finance is the facilitation of exchange between economic actors by promoting a free market of diverse opportunities. Beyond the role of money as a unit of exchange, Levine argues that financial innovation can lower transaction and informational costs which allow for a greater number of transactions and specialization. Permitting specialization allows for diverse lines of research driving innovation which, in the context of the economic model developed in this paper, can increase total factor productivity and economic growth.

While all of these financial functions theoretically lead to economic growth, the expectation that boundless expansion of a financial sector will lead to endless economic growth is misplaced. Although the Schumpeterian production function may not account for nuanced dynamics in the finance-growth relationship, a discussion of the possible harms done by these five functions of finance illustrates this point. While the scale of deposits theoretically allows for optimal investment and in turn the development of innovation, mismanagement of capital due to human error or greed can lead to a worse allocation of resources than if the smaller scale saver had invested themselves. In addition, the idea that financial institutions necessarily produce more information that is valid and transparent as these intermediaries expand in size may be too optimistic. Individual financial institutions are comprised of utility maximizing human beings who will not always have the good of a nation's economy as a whole in mind when making decisions.

In addition to the five functions discussed here, factors such as financial regulation have a strong impact on not only the price premium of finance as reflected in i_t in the model, but possibly more importantly on ensuring some degree of accountability and protection of both savers and borrowers. Although the theory of financial liberalization exceeds the scope of this paper and the dynamics of the basic model, these practical considerations must be considered when examining the final causality results. Understanding returns to economic growth from the expansion of the financial sector extends from this. As argued in this paper, at some point there are negative returns from the functions of finance. This concept is empirically demonstrated when increasing total savings and credit allocation to the private sector no longer promote growth, but hinder it.

Regardless of whether the functions of finance promote or hinder growth maximization, the actual channels by which finance effects growth are also critical to understanding any long-run relationship. Whereas Levine (1997) focuses on establish the functions of finance and its aggregate empirical connection to economic growth, Wachtel (2003) calls for continued attention to the practical connection between finance and growth. Rousseau and Wachtel (2008) point to the dynamics evident in the transmission mechanisms as they operate in reality, predicting that much of the significant finance-growth literature in the near future will continue to isolate these channels for use in policy consideration. Despite the daunting task of unpacking the aggregate, national, industry, and firm specific dynamics for policy application, two generalized transmission mechanisms stand out as being fairly well established in the literature. First, capital accumulation allows for larger scales of operation or investment necessary to induce growth. That being said, country-specific legal, political, and economic frameworks are required for the success of efficient transmission into growth. Second, finance facilitates the process of innovation by the reallocation of capital to fund research and investment opportunities. As in the

Schumpeterian model, the process of creative destruction drives innovation, but innovation requires capital which a financial system can provide.

II.C. Empirical Context

This section provides perspective as to how this paper fits into existing empirical results and methodologies previously employed in the finance-growth literature. Looking at the earliest papers in the field underscores the historical scale of the finance-growth debate. Arguments supporting banks as necessary tools in a modern economy date back to the 1873 work of Walter Bagehot in his groundbreaking book, "Lombard Street: A Description of the Money Market." In addition to demonstrating the importance of the central bank as a lender of last resort, Bagehot provides insights into the importance of controlling the business cycle by anticipating movements and enacting appropriate shifts via interest rates. Focusing on the financial sector rather than central banking, Schumpeter (1911) argues that the financial system acts as a critical intermediary by effectively reallocating resources to newer, more efficient businesses, therefore promoting new technology. Schumpeter concludes that finance serves a necessary function in promoting growth by facilitating innovation. Goldsmith (1969) builds upon the results of Schumpeter and demonstrates simple correlations between financial intermediary assets and economic growth; however, he stops short of drawing a causal interpretation.

Much of the current empirical literature across a variety of methodological approaches confirms the hypothesis that finance causes some degree of growth. In many of these papers, however, the extent by which finance causes growth is dictated by particular circumstances pertaining to size, liquidity, legal oversight, and specific lending practices. Two authors in particular highlight the most prominent lines of research in contemporary empirical literature.

First, Ross Levine has produced a body of work in the field which ranges from empirical investigations into establishing a long-run finance-growth connection to understanding how the relationship may in turn impact specific entities in a given economy. Second, Paul Wachtel (2003) calls for a continued focus on the “black box” of transmission mechanisms linking finance to growth, demonstrated by a range of existing cross-sectional and micro-econometric work. A third branch of thought in the field derives from the work of Robinson (1952) who described finance as following industry demand and economic growth rather than causing it. As Wachtel (2003) explains, few scholars still pursue this third line of thinking and much of the contemporary discussion has moved into more conclusively linking finance and growth and determining the specific ways in which this relationship functions.

The empirical work of King and Levine (1993a) and Levine (2004) concentrates on the hypothesis that finance may indeed cause growth under particular circumstances. The variables in these studies range from a broad measure of the size of a financial system to the degree of liquidity of equity markets. In connection with empirical investigations, Levine (2009) highlights the underlying assumptions in much of his research, explaining that economies with functioning financial systems grow faster than economies without functional financial systems. Developing a Schumpeterian influenced endogenous growth model, Laeven, Levine, and Michalopoulos (2009) examine the channels by which finance may directly impact growth. Following the original model by Schumpeter (1911), finance serves to promote efficient innovation, and the authors argue that forces preventing the development of a financial sector impede innovation, and in turn, growth.

Levine has supplemented broad studies with more targeted investigations into how finance may directly effect growth and under which circumstances it may function most effectively. In Levine and Demirgüc-Kunt (2007), the authors argue that a functioning financial system disproportionately rewards poorer income groups in a given economy by providing capital that would otherwise be unavailable. With these new resources, an economy theoretically tends to reward initiative and hard-work rather than wealth and connections obtained by good fortune or inheritance. In connection with this, Levine, Beck, Demirgüc-Kunt, and Laeven (2008) empirically demonstrate that a financial sector disproportionately rewards smaller firms, possibly by lowering transaction and information costs. Levine (2009) connects this previous research and theorizes that the nature of winners and losers in an open economy, coupled with the disproportionate nature by which finance serves to equalize opportunity, may incentivize some of those on the losing end to interfere with financial development.

Financial system structure plays a disputed role in growth literature. Miller (2005) finds that economies relying on traditional banking alone had put themselves at a disadvantage to those pursuing more disparate and decentralized sources of finance. Using country-specific case studies, Miller argues that an economy such as Japan's, which has built more reliance on traditional banks alone, will be victim to credit crunches with greater frequency than other economies. Despite this evidence, Demirgüc-Kunt and Levine (2001) find that economies will receive greater returns to growth by focusing on overall financial development, rather than on developing a particular type of financial structure, be it a bank based or market based system. Furthermore, Beck, Demirgüc-Kunt, Levine, and Maksimovic (2001) conclude that financial structure has no significant impact on economic growth, industry development, or firm entry. These conclusions imply that although the differences between a bank-based and market-based financial structure may have some impact specific to an individual economy, the determination is marginal by comparison to the development of any type of financial structure as a whole. Berger, Demirgüc-Kunt, Levine, and Haubrich (2004) add to this line of study by explaining that while competition between several banks acting as credit suppliers is good for consumers of debt, a high or low level of concentration in the banking sector has not been shown to impact efficiency with any degree of significance.

Short of Robinson's (1952) claim that finance follows from the development of industry, Paul Wachtel has led another line of research questioning the extent to which finance directly leads to growth. Wachtel focuses on the complexity by which transmission mechanisms operate in reality as opposed to the more manageable dynamics created in an aggregate economic model. Wachtel (2003) describes these mechanisms as the "black box" linking finance and growth, and explains that only by understanding these pathways will policy makers have the information to make necessary adjustments to benefit from the positive effects of finance. Comparing the current state of information to the knowledge of such mechanisms in the money supply and inflation relationship in literature circa the early 1990's, Wachtel implies that researchers still lack information on how to practically implement what has been revealed in aggregate. For Wachtel, micro-econometric analysis such as the industry and firm level research done by Rajan and Zingales (1998) and Beck, Demirgüc-Kunt, and Maksimovic (2005) whose research is detailed later will make up a great deal of the important contributions to the finance-growth discussion in coming years. Wachtel (2003) also expresses concern that the lack of a longer time dimension for financial sector data may hinder further country-specific analysis. Although conclusions must also be made at the panel level, the issue of time series length for financial sector data is addressed in this paper by the use of a panel dimension to supplement limited confidence in country-specific results.

Rousseau and Wachtel (2008) question the ability of financial systems to perpetually increase the rate of growth by increasing in size. Citing how financial liberalization has exceeded legal and informational capacities in the past, the authors point out that the total supply of finance available can extend beyond a growth maximizing point. Particularly in developing economies, the time required to establish a functioning legal framework with which to oversee a financial sector and to train sufficient personnel in finance roles may exceed the pace of liberalization. Such research is particularly insightful when considering how the size of a financial sector may impact growth for the lower income panel examined in this paper.

With this contemporary context in mind, a more thorough examination of the empirical techniques historically employed in the finance-growth field supports an understanding of how the methodology used in this paper uniquely contributes to the literature.[1] This section presents the empirical findings across a range of micro-econometric, cross-sectional, and traditional panel studies while highlighting the weaknesses of these techniques in relation to a long-run causality study as pursued in this paper using panel cointegration methodology.

Micro-econometric studies establish a variety of connections between finance and growth at a country, industry, or individual level. Beck, Demirgüc-Kunt, and Maksimovic (2005) utilize a firm level database spanning 54 countries to asses the impact of financial development on private sector firms by size. The authors conclude that the growth level of smaller firms is most constrained by an under-developed financial system. Rajan and Zingales (1998) approach the finance-growth question from an industry specific view and argue that an established financial system helps to facilitate the transmission of capital. By analyzing the capital needs of a series of industries over a ten year period, the authors demonstrate that high-tech, capital intensive

[1] Literature reviews by Wachtel (2003), Levine (2003), and Pedroni (2007) provided inspiration for this section on methodological context

industries benefit disproportionately from a well functioning, frictionless financial system such as that in the United States. Although an effective tool for analysis across studies of individual industries and countries, the micro-econometric approach in this case requires a priori assumptions regarding the nature of the finance system in the United States and the importance of this system to capital intensive industries. Specifically, Rajan and Zingales (1998) assume that financial markets in the United States are frictionless and that factors influencing industry specific demand for finance are homogeneous across all countries.

Cross-sectional analysis presents an alternate route to exploring the historical relationship between finance and growth on a broader level. A variety of proxies for a financial system have been used to uncover the relationships between financial measurements and growth. King and Levine (1993a) studied the relationship between the size a financial system and growth over the period 1960-1989. One key financial size variable, now frequently referred to as "DEPTH" in the literature, is calculated as the ratio of total liquid liabilities to GDP. In addition to this, their use of a variable for credit to the private sector became a staple in finance-growth literature thereafter. Moving beyond an all encompassing DEPTH measurement, credit to the private sector served as a proxy for the credit allocation function of finance as it inherently incorporates some degree of information gathering in the allocation process. In the study, the authors find that while holding factors such as education, trade, and fiscal policy constant, an increase in DEPTH and credit to the private sector each strongly correlate with an increase in GDP per capita. In addition to this, both DEPTH and credit to the private sector were found to have a strong predictive value for growth when held at the pre-determined point of 1960. Levine and Zervos (1998) retained this focus on credit extended to the private sector. In their research, the authors also included proxies for the size and liquidity of both equity markets and the banking sector as a whole. The investigation concludes that the liquidity of a banking system, rather than size alone, drives a relationship with economic growth.

These cross-sectional investigations present a number of unique methodological shortcomings. Most notably, such approaches can not account for omitted variables which bias estimated slope coefficients in regressions. These biased estimates can not completely distinguish between the true heterogeneity of coefficients and the apparent heterogeneity created by an omitted variable. The non-stationary panel approach adopted by this paper addresses this issue because the long-run relationship established between variables in cointegration links the data at a full order of magnitude above the disturbance created by such omitted variables. In addition, these panel cointegration techniques are an order of magnitude above other issues faced by cross-sectional regressions including endogeneity, simultaneity, and reverse causality.

By establishing a relationship between panels of cross-sectional units for variables in the time dimension, traditional panel techniques overcome some of the methodological issues previously limiting research. Traditional panel methods exploit the time dimension as well as the cross-sectional element of the data, but fail to benefit from the full range of possibilities afforded by use of non-stationary panel methods. Beck, Levine and Loayza (2000) find that private credit maintains a large positive relationship with economic growth while controlling for country-specific effects. Adding to this, Rousseau and Wachtel (2000) apply a similar technique to investigate the impact of equity markets on growth for a panel of 47 countries over a 16 year period. The authors use a variation on the general method of moments technique to estimate a panel of vector autoregressive (VAR) data. The investigation supports earlier claims that equity and finance market liquidity drive per capita output growth, rather than just the size of these markets alone.

While maintaining distinct advantages over other forms of empirical analysis in the finance-growth field, traditional panels lack many features evident in non-stationary panels. Traditional approaches tend to uncover the high-frequency ties between finance and growth rather than the longer-run relationships revealed by non-stationary panels. The reason for this is that in the traditional panel approach, the incorporation of fixed effects tends to absorb longer-run relationships originally present in the data. Non-stationary panel analysis, on the other hand, allows for variables to fluctuate away from each other in the short-run in order to reveal long-run relationships. The non-stationary methodology intuitively benefits an analysis of long-run growth by picking out factors which alter long-run trends rather than relying on high-frequency transitional points.

There are a number of limitations to the non-stationary panel approach as well. First, due to current limitations in the methodology when testing for long-run causality, results will be limited to the bivariate case. Although this paper analyzes three distinct bivariate relationships, each analysis will need to be viewed as independent. In addition, results of the sign of causality test will be limited to a directional statement, and will not be able to quantify the effect. In other words, the test can determine if the current size of the financial system is above, below, or at a growth maximizing level. Growth maximization will be discussed further in relation to the econometric methodology and comprehensively in the discussion of results.

III. The Empirical and Econometric Strategy

The context of existing literature in the finance-growth field places this investigation in the middle of an open and ongoing discussion. As mentioned, this paper utilizes panel cointegration techniques to establish strong long-run relationships between variables. This relatively new methodology draws on the properties of individual time series cointegration supplemented by the addition of a panel dimension. This section will first survey the data used in this analysis. Next, this section will explain non-stationary panel cointegration and its basic application. A step by step overview of non-stationary panel cointegration techniques and a brief overview of how to interpret relevant statistics will reveal how this approach applies to the finance-growth relationship, and why these results add to existing literature in the field. Finally, an overview of the causality tests and corresponding sign test following from Pedroni and Canning (2008) reveal the relationship to cointegration and error correction models.

The choice of variables for use in this investigation has a critical impact on the meaning of final results. Definitions of the most relevant measures of a well-functioning financial system range from the size of the money base to the liquidity of equity markets to qualitative measures of financial law enforcement. All of these potential variables must also be considered by the type and quality of data available for a broad panel of countries over time. The Summers and Heston "Penn World Table" data set has been a primary source of information for many researchers in fields relating to growth. While this source provides only the real GDP per capita series in this investigation, it covers a wide range of countries for over 50 years, making it a solid foundation for such research. Another source for real GDP data is the World Bank databases.

While GDP variables provide the foundation for understanding growth, the choice of financial variables impacts the results and interpretations of this research. The International Monetary Fund through its "International Financial Statistics" provides a great deal of helpful information on the topic. A 2009 update to Levine, Beck, and Demirgüc-Kunt (2000) for the World Bank Economic Review, however, provides a consistent and expansive collection of such variables over a number of years drawing on the IMF and other sources. Their paper, "A New

Database on Financial Development and Structure," provides a thorough account of methodologies used to acquire all data published, and has been intended as a consolidated resource for researchers working in the finance-growth field. Many of the original variables were published as ratios in relation to GDP, possibly to create stationarity, and have been recalculated as a base value for this paper.

Although a large number of financial variables covering a variety of countries comprise the database, only a slim selection of these fit the criteria necessary to create a panel with consistent data stretching from 1960-2007. As mentioned earlier, the time series dimension for these variables is not long enough to place much confidence in country specific results alone, and the panel is critical for adding power to the tests used in this investigation. The choice of financial variables is shaped largely by relevance, availability, and consistency. The data set provides variables on total bank deposits, total financial sector deposits, and total bank credit extended to the private sector over a 48 year time span for 23 countries.

A careful overview of the three variables selected to serve as proxies for the size of a financial system allows for a more direct relationship to the economic model developed earlier. As mentioned, the data on these variables are taken from an update to Levine, Beck, and Demirgüc-Kunt (2000). The authors compiled the data used in this paper from the IMF, and deflated it by an inflation function. For use in this investigation, the variables are then adjusted from ratios relative to GDP to a single variable form. The natural log of these variables is then used for all unit root, cointegration, and causality tests. The first variable, total bank deposits, represents the sum of savings, demand, and time deposits in deposit money banks. This provides a parallel to S_t in equation 4 as a proxy for the base of deposits available for potential credit extension. Next, total financial system deposits incorporates bank deposits and also includes deposits in non-deposit money banks. This variable represents a broader measurement of S_t. As deposit money banks represent incorporated domestic depositories maintaining liabilities on their balance sheet which are available upon demand, an addition of other institutions to this creates a broader measurement. Finally, the variable credit extended to the private sector represents all of the credit extended by deposit money banks to the private sector. In the basic finance-growth economic model, this value may closely proxy for C_t as defined in equation 4. By this definition, total bank credit extended to the private sector may represent the closest proxy to the supply of finance available in sufficient data proportions.

The full panel of 23 countries is broken into two distinct income cohorts, divided according to World Bank definitions of income levels (see Appendix B for the full list of countries). The complete set of tests discussed was also applied to these sub-panels separately to investigate the impact of the size of a financial sector on growth when countries are separated by existing per capita income. The high income group contains the 13 countries from the full panel that have high or upper middle incomes, signifying a gross national income (GNI) per capita in the range of $3,856 or more. Accordingly, the low income group contains the 10 countries in the low and lower middle income groups with a GNI per capita under $3,856. This lower income panel presents a unique angle on the empirical questions posed in this paper, but results for this group must be qualified due to a disproportionate degree of government intervention over the sample period. Data on individual members such as Egypt, India, Pakistan and Sri Lanka may be skewed by such intervention, and although the empirical work was re-run rotating out potential distortions, these exceptions much be kept in mind when interpreting results for the lower income panel.

As discussed in Pedroni (2004), the selection of variables as assessed by their dimensional properties also has significant implications for the econometric results. By proof, asymptotical expansion of the time dimension eliminates the bias created by nuisance parameters in estimation. Pedroni (2004) builds from this by using Monte Carlo simulations to demonstrate that size distortions are small even for small samples. Although the effect of nuisance parameters will not bias results very much, increasing the total time span of data minimizes any existing size distortions. In addition to this, the power of tests rises to nearly 100% as the number of member countries in the panel increases. As small samples still produce results with little bias, the full panel utilized in this paper with 23 member countries over a 48 year time frame for each variable provides more than sufficient dimensions. Although the smaller panel subgroups may sacrifice power by losing members, the analysis should retain enough power to allow for sufficient confidence in results while providing for a more nuanced perspective on the finance-growth relationship.

In the single country form, cointegration represents a linear combination of variables containing unit roots in order to produce a stationary function. Before examining the cointegration process, it is helpful to review what a unit root means in the context of a stochastic difference equation. For a single country, a standard autoregressive process looks like:

$$(7) \qquad y_t = \sum_{j=0}^{\infty} \varphi^j e_{t-j}$$

In vector autoregressive analysis, each variable for a given country must maintain stationarity, meaning that it is mean reverting and that each of its autocovariances is constant. By being stationary, it is defined that in relation to equation 7:

$$(8) \qquad \sum \left|\varphi^j\right| < \infty \quad \text{and} \quad |\varphi| < 1$$

In essence, this means that an innovation e_t to any of the variables for this country will be mean reverting over time and only have a temporary effect.

Investigations involving gross domestic product per capita and a number of other variables included in this finance-growth discussion, however, rely on data which does not conform to the requirements in equation 8. As seen in results of unit root tests in this paper, all variables used are actually unit root processes, meaning that they are integrated of order 1, as defined in equation 7 when:

(9) $$|\varphi| = 1$$

As an aside, it would be possible to difference these time-series which contain a unit root in order to perform a structural vector autoregressive analysis for each of the countries in the panel, but this result would be much less efficient by comparison to cointegration methods. A structural VAR analysis estimates a larger number of parameters with some degree of error which are then accumulated to form a long-run result. Cointegration circumvents this issue by doing the test directly on a smaller number of parameters in the error correction model developed in the methodology. In addition, putting all of the panel countries with two variables each into a structural VAR format requires several a priori restrictions. For the bivariate case, structural identification would require at least one known value by which the variables impact each other in the long-run which would then be applied homogeneously across panel members.

In a single country case, a cointegrating relationship provides a linear combination of two variables, which individually have unit roots, but combine to form a stationary outcome. This can be illustrated for the case where time-series variables F_t and y_t are both integrated of order 1, but some combination defined as:

(10) $$e_t = y_t - \alpha - \beta F_t$$

renders the residuals e_t stationary. The intuition behind this concept is fairly simple. If a given variable contains a unit root, one of the shocks driving this variable has a permanent effect in the long run. By putting two related unit root variables together, however, the combination is mean reverting, and variables will drift together over time if they are cointegrated. It is then the case for this cointegrating relationship that the same shock induces unit root properties in each of the variables individually.

As discussed in the context of methodologies used in previous literature in the finance-growth field, cointegration provides robustness to endogeneity, omitted variable bias, reverse causality, and simultaneity. Cointegrating relationships produce a strong signal that reflects the features keeping the individual variables together in the long run. In fact, this cointegration signal is an entire order of magnitude stronger than the contaminating signals caused by endogeneity and the other potential problems mentioned above. Once again, this becomes clearer when actually analyzing and performing the tests themselves, but the variances of two variables F_t and Y_t as defined:

(11) $$E[F_t - \overline{F}_t]^2 \quad \text{and} \quad E[y_t - \overline{y}_t]^2$$

can be seen as an entire order of magnitude stronger than any problem caused by

(12) $$E[F_t y_t] \neq 0$$

The standard econometric problem of endogeneity occurs as cross-sectional work and traditional panels require $E[F_t y_t] = 0$, otherwise ordinary least squares estimation in a regression like $y_t = \alpha + \beta\ F_t + e_t$ is biased. Under standard regressions:

(13) $$E[\hat{B}_{OLS} - B_0] = \frac{E[F_t e_t]}{E[F_t^{\,2}]}$$

whereby equation 14 defines estimation:

(14) $$\hat{B} = \frac{\sum F_t \, y_t}{\sum F_t^2}$$

The standard cross-sectional regression demonstrated here requires the expectation in the numerator in equation 13 to be 0. Only in this case will an ordinary least squares regression be unbiased and reliable. Under cointegration, on the other hand, the denominators in test statistics created as seen in equation 15 represent the product of two variables which contain unit roots and are integrated of order one.

(15) $$\hat{B} - B_0 = \frac{\sum_{t=1}^{T} F_t e_t \to 0}{\sum_{t=1}^{T} F_t^2}$$

This product therefore is an order of magnitude larger than the numerator which is the product of a variable integrated of order one and an I(0) error term. In effect, the denominator under cointegration becomes infinite relative to the numerator, producing the same consistency as if the numerator had approached 0. Although not a proof, this example demonstrates how these long-run cointegration tests remain immune from a number of common econometric problems.

This intuitive understanding of unit roots and cointegration lays the framework for the panel approach and more technical aspects of tests performed on these non-stationary panels. Although basic non-panel cointegration principles appear to solve many problems in other methodologies, they often require an amount of data not available. Due to an interest in long-run relationships rather than short run dynamics, the time span matters more than frequency of observation measurements such as weekly or monthly data.

The panel dimension exploits existing commonalities across members to make up for a lack of data in the time dimension. These commonalities represent any number of different forms of information gained by adding a number of countries to this analysis (for basic panel time-series notation see Appendix A). As seen below, these panel techniques retain the robust characteristics of cointegration while producing higher power levels with significantly shorter spans of data. In additional to these benefits, specific techniques employed allow for flexible modeling of heterogeneity for each country in the panel. As previously discussed, the contributions of these heterogeneous dynamics across a panel of countries provide second order disturbances to the estimates of long-run parameters. In other words, these country specific dynamics affect the variance of distributions, not the consistency of the tests of interest.

Before moving into the specific application of these methods to the question of establishing a finance-growth relationship, an explanation of the technical details of the tests following from the lecture notes of Pedroni (2009) reveals the specific steps in utilizing this method. First, before proceeding with a panel cointegration test, a test is needed to demonstrate that each variable of interest is I(1), meaning that they are a unit root process. Although a number of methodologies have been developed for this purpose, this investigation will utilize the Im, Pesaran, and Shin (IPS) panel unit root test. Each test brings its own specific view of how variables should be treated. The IPS test is a parametric group mean test. In other words, this type of unit root test models serial correlation dynamics with autoregressive specifications. Although non-parametric tests may be more general, parametric work often produces higher levels of power for small sample sizes. Although this should not be an issue, having a test with superior power for smaller groups will allow for investigations into smaller panel subsets specific to different income levels. In addition to this, the IPS test treats variables of interest as heterogeneously determined. It also constructs the final test estimate on a group mean calculation.

The first step in this IPS test is to calculate the Augmented Dickey-Fuller regression for each member of the panel. The regression for this process looks like (see Appendix A for more details):

$$\Delta\tilde{y}_{it} = \tilde{\alpha}_i + \rho_i y_{it-1} + \sum_{k=1}^{K_i} \varphi_{ik}\Delta\tilde{y}_{it-k} + \eta_{it} \tag{16}$$

The regression ensures that lag selection K_i is large enough to produce white noise in residuals η_{it}. In this regression, estimated by ordinary least squares, $\tilde{\alpha}_i$ represents any country-specific deterministics such as fixed effects. As discussed later in the section on cointegration testing methodology, common time effects are also removed to deal with any cross sectional dependence so that $\tilde{y}_{it} = y_{it} - \bar{y}_t$ where $\bar{y}_t = N^{-1}\sum_{i=1}^{N} y_{it}$.

A step down procedure is utilized in lag selection to ensure that η_{it} is white noise. This step down process tests the significance of each lag beginning with some designated maximum value in order to ensure the most precise estimation for each panel member. While this test allows for heterogeneity in lag length for each panel member, the selection of the designated maximum value must be analyzed for errors. When checking the lag length selection for each of the panel members, any sign of homogeneity should be viewed with caution as the statistical probability of these values being the same, particular if the chosen value is equal to the maximum value, is low. By this logic, the first section of the results in this paper is dedicated to ensuring prevalent heterogeneity in lag selection across panel members for the IPS unit root test. In addition to the issue of maximum value, the lag selection for each member has implications for the size and power of each regression. While choosing too few lags may lead to size distortion, choosing too many lags will eventually lead to the loss of power in hypothesis testing.

Moving back to the IPS test, the second step takes the t-statistic t_{ρ_i} for the null of a unit root for each member and computes:

$$\bar{t}_{\rho} = N^{-1}\sum_{i=1}^{N} t_{\rho_i} \tag{17}$$

Because the distributions of non-stationary processes are rooted in the mathematics of Brownian motion (see Appendix A for details), normal critical values can not be used for immediate analysis of IPS results. This process of summation in the second step utilizes the central limit theorem as the average of these t-statistics moves closer to a normal distribution, but these values are still not yet ready for comparison to ordinary critical values. The final step in the IPS process involves computing the group mean panel statistic by adjusting the mean and variance of the mean t-statistic:

$$Z_{NT}^{IPS} = \sqrt{N/v}(\bar{t}_{\rho} - \mu) \tag{18}$$

In this step, $\mu = E[t_{\rho_i}]$ and $v = Var[t_{\rho_i}]$. It is important to note in this step that the adjustments made do not depend on the data itself, but rather on the t-distribution to which the data is being fit. In addition, complete confidence that this process perfectly converts results into a t-distribution would require an asymptotic amount of data, but this conversion provides a good estimate.

After conversion, the group-mean panel statistic can be compared to the left tail of a t-distribution. This test maintains the null hypothesis of a unit root:

$$\text{H}_0\text{: } \rho_i = 0 \text{ for all i, } Z_{NT}^{IPS} \Rightarrow N(0,1) \tag{19}$$

$$\text{H}_A\text{: } \rho_i < 0 \text{ for all i, } Z_{NT}^{IPS} \rightarrow -\infty$$

For this test, the null is rejected by any value to the left of critical values (see Appendix A for details).

With the IPS test in place, the set up for cointegration testing should be significantly easier as testing for the null hypothesis of no cointegration is very similar to performing an identical unit root test on the estimated residuals of the cointegrating regressions. This paper follows from the work of Pedroni (1999,2004), utilizing a cointegration test with a group mean t-statistic, a close parallel to the augmented Dickey-Fuller test and Im, Pesaran, and Shin methods. In addition to the benefits described earlier, this methodology is also robust to reverse causality which will allow for potential movements between variables in both directions. This piece is particularly critical in the investigation at hand where the working hypothesis involves bi-directional causality between finance and growth.

Similar to IPS methodology, this test begins by running individual panel-member specific regressions, but this time for the cointegrating ordinary least squares output. Before estimation of a cointegrating relationship, the removal of common global time effects that would cause individual panel members to move together over time addresses potential cross sectional dependence. The value $\widetilde{y}_{it}$ replaces y_{it} in equation 21 where:

$$\text{(20)} \qquad \widetilde{y}_{it} = y_{it} - \overline{y}_t \quad \text{where} \quad \overline{y}_t = N^{-1}\sum_{i=1}^{N} y_{it}$$

$$\widetilde{F}_{it} = F_{it} - \overline{F}_t \quad \text{where} \quad \overline{F}_t = N^{-1}\sum_{i=1}^{N} F_{it}$$

In this new form, $\widetilde{y}_{it}$ represents gross domestic product per capita adjusted for common time effects, $\widetilde{F}_{it}$ the various financial sector variables being investigated adjusted for common time effects, and e_{it} the stationary error value. In economic terms, this common time effect could represent anything from a global business cycle swing to a universal development in productivity. The cointegrating relationships between each set of variables remains heterogeneous and specific to each panel member, in addition to allowing for varying short run adjustment dynamics.

This individual cointegration regression is defined for each member i:

$$\tilde{y}_{it} = \alpha_i + \beta_i \tilde{F}_{it} + e_{it} \tag{21}$$

The estimated residuals are then collected from the regression of variable F_{it} on variable y_{it}. An Augmented Dickey-Fuller regression is then estimated utilizing these residuals for each member i:

$$\Delta \hat{e}_{i,t} = \rho_i \hat{e}_{i,t-1} + \sum_{k=1}^{K_i} \gamma_{i,k} \Delta \hat{e}_{i,t-k} + u^*_{i,t} \tag{22}$$

Again paralleling the IPS methodology, a group-mean t-statistic is created in the same form of equation 17 with the null of $\rho_i = 0$. The final steps restandardize the statistic $\bar{t}_\rho$:

$$\chi_{N,T} = N^{-1/2} \tilde{Z}^*_{t_{N,T}} = N^{1/2} \bar{t}_\rho = N^{-1/2} \sum_{i=1}^{N} t_{\rho_i} \tag{23}$$

See Appendix A for an extension on this standardization. Finally, this statistic is adjusted for the properties of the underlying Brownian motion:

$$\frac{\chi_{N,T} - \mu\sqrt{N}}{\sqrt{\nu}} \tag{24}$$

This value represents the final group-mean t-statistic and is used to evaluate the relationship between two unit root time series processes. As in the adjustment done for the IPS test, $\mu = E[t_{\rho_i}]$ and $v = Var[t_{\rho_i}]$. This statistic is evaluated against the same critical values from the left tail of a normal distribution with the null hypothesis of no cointegration. This final step provides adjustment specific to the use of a group mean test, to the removal of time effects, and to the use of only one regressor.

Throughout the process of testing for cointegration, ordinary least squares is utilized in a different way to reveal the strong long-run relationship. Despite the shortcomings mentioned earlier in the context of standard regressions, ordinary least squares picks up on a cointegrating relationship between I(1) variables with tremendous consistency. For cointegration to hold, the combination of variables must be stationary. The variance of a stationary linear combination will be significantly smaller than that for a combination of two unrelated variables and the resulting non-stationary process. As ordinary least squares works by minimizing the variance of residuals for a given regression, this technique can be used to test the residuals themselves for stationarity to evaluate the relationship between I(1) variables in the long run. After establishing the presence of a unit root in each variable of interest, the test for cointegration can now be applied to each of these financial system variables and the GDP per capita series.

After establishing the cointegrating relationships between each of the financial sector variables and growth, a test for long-run causality can be applied. This overview will follow from the methodology discussion in Pedroni and Canning (2008). The intuition behind how such a causality test relates to the cointegration work done thus far helps to clarify how the actual tests work. The cointegrating relationships between each finance variable and growth imply some form of causality, but the sign and direction of this can not be determined from examining these relationships alone. In the case of this investigation for example, the size of a financial system may be found to cause positive growth to a certain point, but GDP per capita growth may also be found to induce an increase, decrease or have no effects on the size of a financial system at a certain level. Building from the useful properties of cointegrated panel work explored thus far, this technique intends to isolate the long-run causality between the finance variables and growth, while allowing for heterogeneous short-run dynamics and cointegrating relationships.

The test itself will exploit these cointegrating relationships for each panel member in each bivariate case to say something about the causal relationship and the positive or negative sign of such causal effect relative to a growth maximizing point. First, each cointegrating relationship is estimated by non-parametric fully-modified ordinary least squares in order to ensure no bias to the second order in estimators or variances. From here an error correction representation is created for each member of the panel while still allowing for heterogeneous adjustment dynamics. This model produces an estimate of the steady state adjustment dynamics between variables for each member which is then used to construct two distinct panel based tests. After establishing the presence of a causal relationship, the sign of this effect can be determined. After estimating the ratio of steady state cointegration adjustments for each panel member, the sign test is constructed from the median of these individual results. As each of the member ratio results follows a Cauchy distribution because it represents a ratio of normals, a bootstrap is required to create a mean and distribution by which to standardize final results.

With a fundamental understanding of the relationship between cointegration and causality and the steps in the test, it is now possible to fully explore the technical details behind how the causality technique works. As stated earlier, after determining the presence of cointegration, the first step in this process is to estimate the cointegration residuals for each individual panel member by a non-parametric fully-modified ordinary least squares method. The residuals of this regression are defined as e_{it}:

$$\widetilde{F}_{it} = \alpha_i + \gamma_t + \beta_i \widetilde{y}_{it} + e_{it} \qquad (25)$$

Here $\widetilde{F}_{it}$ represents each log-level financial sector variable, $\widetilde{y}_{it}$ represents the log-level value of GDP per capita, and e_{it} the stationary error term. The terms $\widetilde{F}_{it}$ and $\widetilde{y}_{it}$ once again account for the removal of common time effects by the processes $\widetilde{F}_{it} = F_{it} - \overline{F}_t$ and $\widetilde{y}_{it} = y_{it} - \overline{y}_t$. These time effects account for both short term disturbances such as global business cycles, as well as common long term effects such as changes in technology affecting the impact of a financial system. The fully-modified method of estimation allows for asymptotic efficiency and eliminates bias to the second order which will allow for this estimation to be treated as truth in later stages.

Having established a cointegrating relationship between each financial sector variable and growth, the residuals can now be used to estimate the error correction representation for each member in the panel. The residuals of the cointegrating relationship then serve to indicate how far each variable is from the long-run steady state point. This representation is estimated for each panel member i.

$$\text{(26)} \qquad \Delta F_{it} = \lambda_{1,i}\hat{e}_{it-1} + \sum_{j=1}^{K_i} R_{ij,11}\Delta F_{i,t-j} + \sum_{j=1}^{K_i} R_{ij,12}\Delta y_{i,t-j} + \varepsilon_{1,it}$$

$$\text{(27)} \qquad \Delta y_{it} = \lambda_{2,i}\hat{e}_{it-1} + \sum_{j=1}^{K_i} R_{ij,21}\Delta F_{i,t-j} + \sum_{j=1}^{K_i} R_{ij,22}\Delta y_{i,t-j} + \varepsilon_{2,it}$$

As mentioned earlier, this error correction model allows for heterogeneous parameters including dynamics via both coefficients and lag truncations. This form uses the differenced values of each unit root variable which in turn provides stationarity.

Before moving into the construction of the causality tests from these estimates, it may help to discuss how this error correction equation has been constructed and develop a more complete understanding of what each of the individual terms signifies. This overview will look at the creation and relationship between a vector moving average representation and a basic error correction representation in order to identify the links needed to produce the final causality tests. This section will provide more specific details by looking at the case of a pair of cointegrated variables F_{it} and y_{it} for an individual member of the panel, and hence the subscript i will be dropped for the duration of this discussion.

From the original cointegration relationship, a vector moving average representation can be created from the stationary differences of the variables (see Appendix A for details).

(28) $$\Delta Z_t = F(L)\varepsilon_t$$

The Z_t represents the demeaned vector of a given pair of variables (F_{it}, y_{it}), ε_t is the vector of white noise innovations $(\varepsilon_{1t}, \varepsilon_{2t})$, and $F(L)$ is the polynomial lag notation for a moving average representation of order q (see Appendix A for details). In the polynomial notation, setting L=1 represents the accumulation of all moving average coefficients in the system, and hence the total long-run responses of vector Z_t to white noise innovations ε_t:

(29) $$F(1) = \sum_{j=0}^{\infty} F_j$$

Each vector of the corresponding 2x2 F(1) matrix then provides information on the long-run responses of one variable to a shock.

Diagram 2: F(1) Matrix

$$F(1) = \begin{pmatrix} F(1)_{11} & F(1)_{12} \\ F(1)_{21} & F(1)_{22} \end{pmatrix}$$

For example, $F(1)_{12}$ represents the accumulated long-run response of a financial sector variable F_{it} to a shock in GDP per capita y_{it}.

Even before moving into the error correction model, it would seem possible to estimate the F(1) matrix by means of reduced form or structural vector autoregressive (VAR) analysis and forgo further cointegration work. Differenced variables in such VAR analysis would also determine the quantitative value of causality rather than just the sign of its effect. Using these accumulated impulse response functions, however, entails some degree of error for each coefficient estimate. The VAR results produces a specific output, but as each parameter estimate possesses some degree of error, the accumulated form lacks the confidence produced by the panel cointegration model which estimates a single parameter in causality testing.

In addition to the vector moving average form, an error correction representation can be created to represent the cointegrating relationship between each pair of variables:

$$\Delta Z_t = \lambda(\beta' Z_{t-1}) + \sum_{j=1}^{K} R_j \Delta Z_{t-j} + \varepsilon_t \tag{30}$$

While Z_t represents the same vector of variables, the remaining terms provide insight into the construction of the full error correction model displayed in equations 26 and 27. β represents the cointegrating vector relating the pair of variables and is defined as $\beta = (1, -\beta_1)'$. The component $\beta' Z_{t-1}$ is then interpreted as the error correction term for the steady state of the cointegrating relationship between variables F_t and y_t. The most critical piece of equation 30 for the purposes of the causality investigation is the coefficient λ found in front of $\beta' Z_{t-1}$. As $\beta' Z_{t-1}$ represents steady state error correction, λ can be described as the steady state adjustment vector $\lambda = (\lambda_1, \lambda_2)'$. This term describes movements in the model as the cointegrating relationship moves. The summation term $\sum_{j=1}^{K} R_j \Delta Z_{t-j}$ describes the transitory dynamics specific to this member within the panel with a given number of lags K. Finally, ε_t is once again the vector of white noise innovations as in the full error correction model.

With this set up complete, the technical overview returns to the full panel. The Granger representation theorem from Engle and Granger (1987) provides a critical implication which connects the VMA and error correction representations and allows for a sound test of causality between cointegrated variables. The theory states that the total long-run response matrix F(1) must contain a singularity so that:

$$(31) \qquad F(1)\lambda = 0$$

where λ defines the steady state adjustment vector $\lambda = (\lambda_1, \lambda_2)'$ describing movements as the cointegrating relationship moves. This theory in turn implies a number of further rules governing the long-run relationship between variables.

First, equation 31 implies that:

$$(32) \qquad F(1)_{21}\lambda_1 + F(1)_{22}\lambda_2 = 0$$

Equation 32 can be reorganized if we can assume that $F(1)_{22} \neq 0$. This assumption means that the long-run response of GDP per capita to a shock in GDP per capita will not be zero. This makes sense both econometrically as a unit root variable and intuitively in terms of the impact of a positive shock to GDP per capita. In addition to this, cointegration ensures that both elements of λ as shown in equation 32 can not be zero. In a cointegration relationship, an error correction mechanism must exist and must adjust in the long-run to a shock. These definitions require that innovations in the financial sector variable F_t have no long-run causal effect on GDP per capita growth y_t as defined by $F(1)_{21} = 0$ if and only if $\lambda_2 = 0$. This final proposition allows for a test of causality defined by the hypothesis:

(33) $\quad$ H_o: $\lambda_2 = 0$; No long-run causality $F_{it} \rightarrow y_{it}$

H_A: $\lambda_2 \neq 0$; Long-run causality $F_{it} \rightarrow y_{it}$

This test can then also be extended to the reverse case by testing λ_1.

This section will complete the proofs necessary to determine the sign of causality before describing the two specific causality tests. After the presence of causality has been determined, some ratio will be required to determine a positive or negative impact relative to a growth maximizing point. A normalization of $F(1)_{22}$ as greater than zero allows for such a ratio. This restriction makes intuitive sense as a unit root variable undergoing a positive shock will likely affect itself in a positive way. In the model employed in this paper, this statement would imply that an innovation to the unit root variable GDP per capita would have a long-run positive impact on itself. Thus given that causality does exist, meaning that $F(1)_{21} \neq 0$, and rearranging equation 32:

$$(34) \qquad F(1)_{21} = -\frac{\lambda_2}{\lambda_1} F(1)_{22}$$

From here, as vector $F(1)_{22}$ has been normalized as positive:

$$(35) \qquad Sign[F(1)_{21}] = Sign[-\frac{\lambda_2}{\lambda_1}]$$

In other words if a causal relationship exists running from a financial sector variable to GDP per capita growth, the sign of that impact would be defined as the sign of $-\frac{\lambda_2}{\lambda_1}$.

Returning to the specific tests used to evaluate causality, the first application of the long-run causality methodology is in the group mean test. First, the test requires the establishment of the error correction representation seen in equations 26 and 27. For the case of causality running from finance variable F_{it} to GDP per capita growth y_{it}, the test then pools the λ_2 values:

$$(36) \qquad \overline{\lambda}_2 = N^{-1} \sum_{i=1}^{N} \hat{\lambda}_{2,i}$$

This test then looks at a null hypothesis of no causality from F_{it} to y_{it} by producing a group mean t-statistic:

$$(37) \qquad \bar{t}_{\lambda_2} = N^{-1}\sum_{i=1}^{N} t_{\lambda_{2,i}} \Rightarrow N(0,1)$$

In this test, the value $t_{\lambda_{2,i}}$ represents the individual t-statistics for the significance of $\lambda_{2,i}$ as shown in equation 36. To test for causality running in the opposite direction, the test is applied to the λ_1 values. This group-mean examination for causality is a normally distributed, two-tailed test.

The other test for causality employed is the Lambda-Pearson (Fisher) Statistic. Maintaining a null hypothesis of no causality, this test looks at the p-values for the individual t-statistics on $\lambda_{2,i}$ used in equation 37. This test is defined as:

$$(38) \qquad P_{\lambda} = -2\sum_{i=1}^{N} \ln p_i$$

The test is one-tailed and defined by a chi-squared distribution.

Although both of these tests maintain a similar hypothesis structure for the case of a homogeneous panel, the combination of the two can provide more nuanced results for heterogeneous panels as defined by:

$$(39) \qquad \lambda_{2,i} \neq \lambda_2 \forall i$$

In the two-tailed group mean test, the individual t-statistics are compiled and then aggregated as depicted in equation 37. In the case of heterogeneity, the group-mean test asks whether long-run causality exists on average. In this case, a number of members could end up having values for $\lambda_{2,i}$ both above and below zero. It could even be possible that all $\lambda_{2,i}$ values are non-zero, yet end up with zero as the average, producing a no long-run causality on average result. In contrast to this, the Lambda-Pearson test looks at the p-values, or significance of each t-statistic, as defined by equation 38. The conclusion in this case will be whether long-run causality exists pervasively throughout the panel. In addressing the results of all causality tests, this paper will utilize the information derived from both sources in order to make the most robust inferences into the true nature of the relationship between finance and growth.

As mentioned earlier, the final piece of this investigation is to identify the sign of any causal relationships relative to a growth maximizing point as revealed by the ratio defined in equation 35. Although this metric appears simple enough when originally derived, it relies on the median of individually estimated ratios of normals which follow Cauchy distributions. These types of distributions lack defined variances and require bootstrap techniques in order use the established median and estimated vector error correction models to produce a simulated variance. Although much of the math behind the Cauchy distribution itself exceeds the scope of this paper, an overview of the final bootstrapping technique provides the methodological answer to this distribution problem.

To create a distribution for which this sign test can be applied requires the bootstrapping of a multivariate vector autoregressive. Before proceeding, stationary variables are required to prevent a distorting influence of time, which in non-stationary variables matters in an absolute sense. If the bootstrap were to operate on a non-stationary VAR, the results might be heavily influenced in either direction by reliance on the time dimension. After creating stationary variables, it is also important that they remain cointegrated, as this is a core underlying assumption of the causality analysis. Although initially intuitive to work with the differenced variables ΔF_{it} and Δy_{it} from equation 25, there is no guarantee that these will remain cointegrated in the long run. These two differenced variables are likely to demonstrate some observable dependence and comparable adjustment dynamics, but the steady, long-run relationship will be lost.

The base variables for the bootstrap will then be (see Appendix A for notes on polynomial lag notation):

$$(40) \qquad \hat{R}(L)\begin{pmatrix} \Delta F_{it} \\ e_{it} \end{pmatrix} = c + \mu_t$$

By definition of cointegration, both ΔF_{it} and e_{it} are known to be stationary. The difference of a unit root variable will produce stationarity and the residuals from the cointegrating regression will be I(0) if cointegration exists. The bootstrap is then used to produce 1000 realizations of these variables in the form:

$$(41) \qquad \begin{pmatrix} \Delta \dot{F}_{it} \\ \dot{e}_{it} \end{pmatrix}$$

Accumulating these discrete realizations produces $\dot{F}_{it}$. This accumulated form can then be used to generate:

$$(42) \qquad \dot{y}_{it} = \hat{\alpha}_i + \beta_i \dot{F}_{it} + \dot{e}_{it}$$

This new form of the cointegrating relationship can then be used for final sign testing as it has a definite variance which is created in the bootstrapping process.

IV. Empirical Results

Before testing for the presence of causality and the sign of its effect, it must first be determined that each pair of variables contains a unit root and forms a cointegrating relationship for the panel. As the section dedicated to methodology covers the technical details of these tests, the empirical results will focus primarily on interpreting findings in the context of the economic question posed.

With a panel of 23 countries over a 48 year span, an analysis can be conducted on individual variables to test for the presence of a unit root. This proof of non-stationarity will ensure that each variable is indeed fit for a cointegration test. Unit roots are a prerequisite for further investigation as cointegration represents a linear combination of non-stationary variables and renders the combination stationary. As described in the methodology, the selection of a maximum value for the beginning of the lag selecting step down procedure in this test has important implications for the test's accuracy. If the step down procedure selects a homogeneous pool of lags across individual panel members, a distorting error may be present in the process. The odds of selecting the same lag lengths for all members would be statistically improbable. For this reason, the lag selection must be examined to ensure heterogeneity, and an example of the results for such a test is included in Appendix B.

After ensuring proper lag selection, the individual series can be inspected for unit roots. In the context of seeking to understand the impact of changes in financial sector variables on economic growth, all variables are evaluated in the log level throughout these tests. As noted, the following results were obtained by the Im, Pesaran, and Shin (IPS) methodology and allow for heterogeneous short-run dynamics and lag selection as well as removing common time effects (See Appendix A for critical values).

Diagram 3: IPS Panel Unit Root Test

	IPS-ADF Statistics
Log GDP per Capita	2.587
Log Total Bank Deposits	-1.004
Log Total Financial System Deposits	-0.751
Log Bank Credit to the Private Sector	-0.953

Note: Symbols denote *10% **5% ***1% rejections

With a null hypothesis of a unit root, the results indicate that none of these variables are stationary and are indeed non-stationary for all members in the full panel (see equation 19 for details). As noted, the basic economic interpretation of a unit root implies that some shock to the variable produces a permanent, long-run effect.

After ensuring that each variable contains a unit root, each pairing of a financial sector variable and GDP per capita can be tested for the presence of cointegration. Using a step down procedure with a base number of lags at 10, the panel cointegration test produces the following results after removing common time effects.

Diagram 4: Full Panel Cointegration Tests with Log GDP per Capita

	Group ADF Statistic
Log Total Bank Deposits	-3.333***
Log Total Financial System Deposits	-3.509***
Log Bank Credit to the Private Sector	-3.509***

Note: Symbols denote *10% **5% ***1% rejections

As indicated by numbers beyond the one-tailed test critical points, all three variables reject the null of no cointegration for the full panel at the 1% significance level (see Appendix A for critical values). As the stationary combination of two individual unit root variables, these cointegrating pairs imply a long-run relationship. Although the short-run adjustment dynamics may cause them to move apart, the variables will drift together and return to equilibrium established by the cointegrating relationship in the long-run.

Because causality testing requires cointegration as a prerequisite, the panel cohorts separated into higher and lower income groups must also be tested for cointegration for all variables. The results of these tests indicate a rejection of the null of no cointegration for all six cases, and are included in Appendix B.

As demonstrated in the methodological section, the presence of each bivariate cointegrating relationship ensures that some form of long-run causality exits for each pair. As in the two tests already utilized, this causal relationship is estimated for each member of the panel before constructing a test for the full panel. The results of both the causality test and test for the sign of causality are presented for the relationship between log total bank deposits and log GDP per capita in Diagram 4 below. The results of the tests include the value for the country-specific estimates of λ_2 and λ_1 as seen in equations 26 and 27 as well as the corresponding test statistic and p-values. The final column presents an estimate of the sign of causality running from F_{it} to y_{it}, when causality does exist, as the ratio of $-\frac{\lambda_2}{\lambda_1}$ as presented in equation 35.

Diagram 5: Individual Member Results in Causality Test for Total Bank Deposits

	λ_2: f_{it} causing y_{it}			**λ_1: y_{it} causing f_{it}**			**$-\lambda_2 / \lambda_1$**
Country	Estimate	Test	P-Value	Estimate	Test	P-Value	Median
Canada	-0.05	-1.84	(-0.07)	-0.28	-2.99	(0.00)	-0.17
Croatia	-0.03	-1.60	(-0.11)	-0.19	-1.79	(-0.07)	-0.16
Denmark	-0.01	-0.53	(-0.60)	-0.21	-2.81	(0.00)	-0.04
Dominican Republic	0.00	0.12	(-0.91)	-0.29	-2.60	(-0.01)	0.01
Ecuador	-0.02	-0.64	(-0.52)	-0.42	-3.68	(0.00)	-0.04
Egypt	0.09	1.12	(-0.26)	-0.31	-1.97	(-0.05)	0.28
El Salvador	-0.01	-0.67	(-0.50)	-0.39	-1.52	(-0.13)	-0.04
Guatemala	0.00	0.25	(-0.80)	-0.13	-1.26	(-0.21)	0.04
Haiti	-0.02	-1.04	(-0.30)	-0.10	-1.69	(-0.09)	-0.18
Honduras	0.05	1.57	(-0.12)	-0.20	-2.05	(-0.04)	0.25
India	0.00	0.01	(-1.00)	-0.26	-2.22	(-0.03)	0.00
Jamaica	0.03	0.94	(-0.35)	-0.32	-2.74	(-0.01)	0.10
Malaysia	0.03	1.06	(-0.29)	-0.11	-1.40	(-0.16)	0.23
New Zealand	0.00	0.01	(-0.99)	-0.11	-1.84	(-0.07)	0.00
Pakistan	-0.04	-2.09	(-0.04)	-0.21	-2.40	(-0.02)	-0.19
Panama	0.00	0.00	(-1.00)	-0.11	-1.78	(-0.07)	0.00
Philippines	-0.02	-0.85	(-0.39)	-0.17	-2.40	(-0.02)	-0.12
Sri Lanka	-0.03	-2.77	(-0.01)	-0.08	-1.41	(-0.16)	-0.44
Switzerland	0.00	0.03	(-0.97)	-0.48	-3.31	(0.00)	0.00
Trinidad and Tobago	-0.19	-3.87	(0.00)	-0.38	-0.91	(-0.36)	-0.49
United Kingdom	-0.01	-0.61	(-0.54)	-0.53	-3.94	(0.00)	-0.03
United States	-0.01	-1.18	(-0.24)	-0.38	-1.66	(-0.10)	-0.04
Venezuela	-0.03	-1.08	(-0.28)	-0.20	-2.06	(-0.04)	-0.13

Member-specific results include interesting findings, particularly in the context of country specific policy recommendations; but as reiterated throughout this paper, the limitations of data in the time dimension likely cause inaccurate estimation. The methodology utilized in this investigation seeks to supplement this limited time dimension with panel data to add confidence in final results. The country specific results for the other two causality pairings are included in Appendix B for reference.

The results of the panel test for causality, and the sign of that relationship where appropriate, are presented for each of the three finance variables in Diagrams 6-8. Results are separated into three groupings of two rows, representing the results for the full panel, the high income panel, and the low income panel respectively. The number of members in each of these panels is indicated in parenthesis. The top row for each panel presents the findings for the group mean causality test, and the lower row the findings for the Lambda-Pearson tests as described in the section on methodology. The columns in diagrams 6-8 are broken up in the same manner as the country specific results presented in diagram 5. Once again the final column includes the value of the sign test and in parenthesis below it is the standard error for this result.

Diagram 6: Causality Test for Total Bank Deposits

Member Grouping		λ_2: f_{it} causing y_{it}			λ_1: y_{it} causing f_{it}			$-\lambda_2 / \lambda_1$
		Estimate	Test	P-Value	Estimate	Test	P-Value	Median
All (23)	Group mean	-0.01	-0.59	(0.28)	-0.25	-2.19	(0.01)***	-0.04
	Lambda-Pearson		72.00	(0.01)***		175.90	(0.00)***	SE: (0.03)
High Income (13)	Group mean	-0.02	-0.63	(0.26)	-0.32	-2.38	(0.01)***	-0.04
	Lambda-Pearson		35.96	(0.09)*		111.88	(0.00)***	SE: (0.03)
Low Income (10)	Group mean	-0.00	-0.31	(0.38)	-0.21	-1.89	(0.03)**	-0.03
	Lambda-Pearson		23.34	(0.27)		60.71	(0.00)***	SE: (0.06)

Diagram 7: Causality Test for Total Financial System Deposits

Member Grouping		λ_2: f_{it} causing y_{it}			λ_1: y_{it} causing f_{it}			$-\lambda_2 / \lambda_1$
		Estimate	Test	P-Value	Estimate	Test	P-Value	Median
All (23)	Group mean	-0.01	-0.58	(0.28)	-0.26	-2.19	(0.01)***	-0.04
	Lambda-Pearson		74.86	(0.00)***		174.22	(0.00)***	SE: (0.03)
High Income (13)	Group mean	-0.02	-0.65	(0.26)	-0.30	-2.26	(0.01)***	-0.04
	Lambda-Pearson		37.31	(0.07)*		102.31	(0.00)***	SE: (0.03)
Low Income (10)	Group mean	-0.00	-0.32	(0.37)	-0.22	-1.91	(0.03)**	-0.02
	Lambda-Pearson		23.77	(0.25)		62.00	(0.00)***	SE: (0.06)

Diagram 8: Causality Test for Total Credit Extended to the Private Sector

Member Grouping		λ_2: f_{it} causing y_{it}			λ_1: y_{it} causing f_{it}			$-\lambda_2 / \lambda_1$
		Estimate	Test	P-Value	Estimate	Test	P-Value	Median
All (23)	Group Mean	-0.01	-0.31	(0.38)	-0.23	-2.02	(0.02)**	-0.04
	Lambda-Pearson		64.91	(0.03)**		160.71	(0.00)***	SE: (0.03)
High Income (13)	Group mean	-0.01	-0.15	(0.44)	-0.22	-1.81	(0.04)**	-0.04
	Lambda-Pearson		38.88	(0.05)**		84.78	(0.00)***	SE: (0.03)
Low Income (10)	Group mean	-0.01	-0.48	(0.32)	-0.30	-2.39	(0.01)***	-0.01
	Lambda-Pearson		22.79	(0.30)		85.77	(0.00)***	SE: (0.04)

Note: Symbols denote *10% **5% ***1% rejections

The following discussion will first provide an overview of the causality test results and continue with a more nuanced look at the findings, including the results of the test for the sign of direction for causality where appropriate (see Appendix A for critical values).

A number of patterns emerge from the causality results in Diagrams 6-8. In the case of all three variables for each of the three panel subgroups, the tests establish long-run causality running from economic growth to the size of the financial sector, both on average and pervasively throughout the panel. As established in the methodology, under the assumption of heterogeneity of λ among panel members, the group mean tests look at causality for the panel on average. Supplementing this information, the Lambda-Pearson test uses the p-values of the tests to demonstrate whether causality exists pervasively among panel members. With few exceptions the null hypothesis of no causality is rejected up to the 1% level. This result confirms the expectation developed in the literature and in the model used in this paper: as an economy grows, the financial sector, as measured by these three variables, expands.

Next, a number of trends exist within the tests for long-run causality running from the size of a financial system to growth. Looking first at the full panel of 23 countries, causality test results across all three variables indicate pervasive causality. Although the lack of significance on the group mean test indicates that this effect cancels out to be zero on average, causality from the size of a financial sector to economic growth exists pervasively for members of the full panel. The null hypothesis of no pervasive causality for the full-panel Lambda-Pearson test is rejected at the 1% level for bank deposits and financial system deposits, and is rejected at the 5% level for credit extended to the private sector. This result confirms the hypothesis of bi-directional causality between finance and growth.

The two income subgroups also present a number of trends across the three variables in tests for long-run causality running from the size of finance variables to growth. The higher income group causality tests parallel the full panel tests by establishing pervasive causality for all three variables which have effects that cancel out on average. Contrary to these findings, the low income group confirms the null hypothesis of no long-run causality, either on average or pervasively, from any of the three finance variables to growth.

The causal impact of economic growth on the size of a financial system will be addressed before a more nuanced discussion of finance based causality. As mentioned, the finding that economic growth causes the expansion of a financial sector as measured by all three variables has been supported in the literature, and is indeed an underlying assumption of some investigations such as Levine (2004). This panel work confirms that the causal relationship holds true across income groups both on average and pervasively. The results of the group median test for the sign of causality also support existing work in the field (see Diagram vii in Appendix B for details). As each result signifies a positive value outside of standard error, sign test results indicate that an increase in economic growth will continue to cause the expansion of the financial sector both on average and pervasively across the full panel of 23 countries.

Although growth has been found to cause the size of a financial system in the long-run, this investigation contradicts the claim by Robinson (1952) that the expansion of industry causes finance only, and instead establishes bi-directional causality. The discussion will examine each of the panel groups separately as the results for each of the three financial sector variables follow the same pattern with respect to the panels.

The full panel causality results indicate that for all three variables, a movement in the size of a financial system causes a change in long-run economic growth pervasively across panel members. Although the average long-run effect of this relationship as measured in the group mean test cancels out on average, the growth of many individual countries is effected by the size of their financial system. The sign of this long-run effect, however, is pervasively negative across the full panel for all three variables. This result indicates that the full panel of countries is pervasively overinvested in developing the size of their financial systems relative to a growth maximizing point. For the full panel then, additional investment in expanding a given nation's financial system crowds out other possible macro investments which will have superior returns to growth. This overinvestment thus diminishes from growth maximization pervasively across the full panel. By drawing macro level investment away from other industries, overinvestment diminishes the long-run benefit of the size of the financial system. This impact thus renders the long-run net causal effect on growth negative for the full panel.

The results for the high income panel for all three variables closely mirror the findings in the full panel. Once again, the causal impact of the size of a financial system on growth is found to be zero on average, but this hides the reality that finance causes a non-zero long-run effect pervasively across the high income panel. In addition, the sign of this long-run effect is again seen as negative pervasively among panel members. The sign test result implies that high income countries are pervasively overinvested in growth relative to other investments which would provide higher returns to economic growth.

Finally, the low income panel results contradict the hypothesis of bi-directional causality by failing to reject the null hypothesis of no causality from finance to economic growth. This rejection holds for both the group mean test and Lambda-Pearson test, meaning that no significant causal relationship is seen either by average effect or pervasively across the panel. Results indicate that changing the size of a financial sector for these countries will not have a permanent effect on long-run economic growth. Rather than investing in finance, low income countries should allocate these resources in any number of alternative industries which have been found to impact growth, such as infrastructure as noted by Pedroni and Canning (2008). These results, however, must be qualified by the smaller panel dimension and that several individual member countries underwent substantial government intervention in financial markets throughout this 48 year time span. To account for this, the panel was retested rotating out potential exceptional countries, and although the same result of no long-run causality was found, these possible distortions must be kept in mind.

V. Conclusions

The long-run relationship between the size of financial systems and economic growth remains as relevant as ever. Despite developments in the field, policy makers are still presented ambiguous findings on the finance-growth relationship in the face of a global economic crisis widely attributed to unbridled financial systems. By applying the panel causality tests of Pedroni and Canning (2008) to this question for the first time, this empirical investigation attempts to add confidence when discussing the aggregate nature of the long-run relationship in the presence of limited time series data for specific countries. By accounting for the possibility of reverse causality, this approach isolates the potential effect that the size of a financial system has on growth. The methodology applied not only identifies causality, but also reveals the sign of this relationship relative to a growth maximizing point. For policy makers, these results may hope to inform decisions on the macro allocation of resources in developing a financial sector that maximizes economic growth.

Results demonstrate that the size of a financial system as measured in separate investigations by bank deposits, financial system deposits, and credit extended to the private sector cause economic growth pervasively among panel members for both the full and high income panels. Although the long-run effects cancel out on average, the Lambda Pearson test identifies that a substantial portion of the countries in these two panels demonstrate bi-directional causality between finance and growth. As noted earlier, the variables bank deposits and financial system deposits represent two proxies for the base of deposits available for credit extension denoted as S_t in the basic Schumpeterian production function. In addition, credit extended to the private sector serves as a proxy for the supply of finance denoted as C_t in the production function. Finance may then impact growth in accordance with the core functions of finance as outlined by Levine (1997) and by the corresponding transmission mechanisms as discussed in the literature review.

Complicating this causal relationship, the group median sign test for the full and high income panels reveals that the countries in each of these groups are pervasively overinvested in the financial sector relative to a growth maximizing point. Intuition developed throughout this investigation supported by existing literature suggests a number of causes for this result. First, as pointed out in Levine (2004), a larger investment in developing the quality of finance by means of regulatory environment, employee training, or otherwise, may increase the efficiency of financial intermediaries. This point is reflected in the basic production function developed earlier in equations 3 and 4. The quality of finance may have large ramifications for the supply of finance as a function of institutional efficiency and the deposit base as well as for the cost of finance. A second reason for this overinvestment may simply be that the current level of economic activity in many countries in these panels is oversupplied finance, and by simply reallocating some of these resources to other industry segments, a higher growth level could be achieved.

The low income panel, on the other hand, rejected the hypothesis of bi-directional causality both on average and pervasively. Rather, causality was found only to run from economic growth to the size of a financial system. A series of possible explanations might help to account for this result's deviation from the other panels. First, as mentioned throughout the paper, a number of panel members in this group underwent substantial government intervention throughout the 48 year time span covered by the data. Although this alone may not nullify results, it should certainly qualify the findings for this group. Second, as a modification on the work of Robinson (1952), financial sector growth in developing economies may only be driven by economic growth. In her model, the supply of finance measured by credit extended is a function of potential profits and the general economic climate whereas finance serves to promote growth only at lower order of magnitude. The model could be extended to say that some undefined characteristics of lower-income, developing economies require a base level of economic development before finance can significantly cause growth. A third, more plausible, explanation for this difference is the exceedingly fast pace of financial liberalization in many developing economies. As discussed, some base level of regulation and financial knowledge is required before an economy can benefit from a financial system. While an overly general reading of the results in this study may indicate that lower income economies should divert all resources away from the financial sector and into other industries, this would be practically implausible. Although no long-run causality has been established for this low income group, some baseline macro investment in the training of finance employees and in developing a regulatory framework may facilitate the functions of finance and develop the transmission mechanisms to growth.

This investigation demonstrates that a strong, long-run causal relationship runs from the size of a financial system to economic growth pervasively for a number of countries. Despite this relationship, the results also indicate that as a whole, countries are overinvested in developing the size of finance, and in lower income countries this long-run relationship may be absent all together. While finance provides the capital necessary for efficient innovation and economic growth, policy makers should keep an eye on the supply of this credit relative to demand. In an age of financial mega-profits, some distortion in the marketplace may drive the current suboptimal size of the financial sector. This study has also been limited in conclusions to the three panels of countries, but as more data becomes available over time, country specific studies will provide critical analysis to policy makers. In addition, the levers of policy implementation are, of course, much more specific than the aggregate issues addressed here. Following in the direction of Wachtel (2003), the finance-growth field requires further research into specific transmission mechanisms, and empirical evaluations of various tools for controlling the quantity and quality of finance.

VI. Appendices

Appendix A: Further Derivations

This section is intended to clarify mathematical and econometric derivation too lengthy to be produced in the main text of this paper. The majority of this section extends on information introduced in section III.

A basic means of notation is critical to an understanding of non-stationary panel time series work. The data can be pictured as series in three dimensions. The time dimension is represented as $t = 1,...,T$; the cross sectional dimension as $i = 1,...,N$; and finally the number of variables as $m = 1,...,M$. For clarity, the cross sectional dimension in this case is the individual countries that are the "members" of the panel. Each of these members then is a vector with M number of variables observed over time span T. The panel then has total dimensions $TxNxM$.

A base autoregressive equation AR(P) takes the form:

(i) $$\Delta y_t = \alpha + \varphi_1 \Delta y_{t-1} + ... + \varphi_p \Delta y_{t-P} + \varepsilon_t$$

A system of autoregressive equations then forms a system where $Nx1$ variables defined as Δz_t are equal to a $Nx1$ coefficient matrix c, plus a Nx1 vector white noise μ_t, plus the bulk of the stochastic difference equation $\sum_{j=1}^{P} R_j \Delta z_{t-j}$ so that the combined form looks like:

(ii) $$\Delta z_t = c + \sum_{j=1}^{P} R_j \Delta z_{t-j} + \mu_t$$

These equations can be simplified by using polynomial lag notation so that:

(iii) $$R(L)\Delta z_t = c + \mu_t$$

Here R(L) is a matrix with dimensions NxN. This notation realized at $L = 1$ represents the long-run where $R(1) = R_0 - \sum_{j=1}^{P} R_j$, implying $(R_0(1)^0 - R_1(1)^1 - ... - R_p(1)^p)$ and the short run as evaluated at $L = 0$ produces $R(0) = (R_0(1)^0 - R_1(1)^1 - ... - R_p(1)^p) = R_0 = Identity$. By the Wold Representation Theorem, a vector moving average (VMA) representation form exists because the original VAR was stationary. This new form is denoted in similar notation as $\Delta z_t = \tilde{c} + F(L)\mu_t$ The two forms are invertible by $F(L) = R(L)^{-1}$. This vector moving average form also allows for more practical interpretation as the coefficients quantify the ceteris paribus impact of a given unanticipated "shock" on a specific variable.

As seen throughout this paper (equation 16 in particular), the augmented-Dickey-Fuller test for unit roots plays a key role throughout the panel investigations. For a complete understanding of these methods, it helps to step through the exact nature of this test. This begins by representing a general unit root process as $y_t = c + y_{t-1} + \sum_{j=1}^{\infty} R_j \Delta y_{t-j} + \mu_t$ where μ_t is independent and identically distributed white noise. Next, this process is approximated as an AR(P) expression:

$$\text{(iv)} \qquad y_t = c + \varphi y_{t-1} + \sum_{j=1}^{P} R_j \Delta y_{t-j} + \mu_t$$

Although this equation could be used as the test with the null hypothesis of $\varphi = 1$ against an alternative hypothesis of $\varphi < 1$ to determine if variable y_t contains a unit root, it can be simplified further for the sake of easier testing in computer programs by subtracting y_{t-1} from each side. After this simple subtraction, the final form looks like:

(v) $$\Delta y_t = c + \rho y_{t-1} + \sum_{j=1}^{P} R_j \Delta y_{t-j} + \mu_t$$

First using a step down procedure to choose the order of the equation as discussed in the main text, the t-test can be compared to the null of a unit root:

(vi) H_0: $\rho = (\varphi - 1) = 0$ if and only if $y_t \sim I(1)$

H_A: $\rho = (\varphi - 1) \leq 0$ if and only if $y_t \sim I(0)$

The distribution is not standard, and so (unless simulating new critical value estimates) the test generated must be compared to statistics approximating critical values.

Although a full investigation of Brownian motion and quantum mechanics is far beyond the scope of this paper, it helps to get a sense of the distributions these non-normal processes take. As noted in Pedroni (2009), the limit distribution for the ADF unit root test where $W(r)$ represents standard Brownian motion is characterized as:

(vii) $$t_\rho \Rightarrow \left(\int_{r=0}^{1} W(r)dW(r) - W(1) \int_{r=0}^{1} W(r)dr \right) \left(\int_{r=0}^{1} W(r)^2 dr - \left(\int_{r=0}^{1} W(r)dr \right)^2 \right)^{-1/2}$$

While this distribution does not prove why specific adjustments were made throughout the paper, it provides a sense of how necessary these adjustments are to be able to compare the statistics to normally distributed critical values.

The following normally distributed, one-tailed critical values were used throughout the investigation at the 10%, 5%, and 1% respectively: -1.282, -1.645, and -2.326.

Appendix B: Supplementary Tables

The supplementary tables in this Appendix provide further context and present results that were too lengthy to produce in the body of the paper.

Diagram i provides a list of the 23 countries used in the full panel. The list is subdivided into the two income subpanel groups. As mentioned in the discussion on data, these subpanels were created according to World Bank definitions of per capita income groups. High and upper middle income countries were placed in the high income panel, and low and lower middle income countries were placed in the low income panel.

Diagram i: Countries in Panel by Income Group, 1960-2007

High Income	Low Income
Canada	Ecuador
Croatia	Egypt
Denmark	El Salvador
Dominican Republic	Guatemala
Jamaica	Haiti
Malaysia	Honduras
New Zealand	India
Panama	Pakistan
Switzerland	Philippines
Trinidad and Tobago	Sri Lanka
United Kingdom	
United States	
Venezuela	

Next, diagram ii provides the results of the investigation into the lag selection in the step down procedure used in testing for unit roots. As explained in the methodology, it is important to check for heterogeneity across this selection, as the statistical probability of the same lag length being chosen across many panel members for a given variable is low, and may indicate an error in the step down process. This example result for the case of testing for unit roots in the full panel demonstrates sufficient heterogeneity.

Diagram ii: Lag Selection for Step-Down Procedure in Full Panel Unit Root Test

Country	Member Specific Lag Length Selection			
	Log GDP per Capita	Log Total Bank Deposits	Log Total Financial System Deposits	Log Bank Credit to the Private Sector
Canada	7	14	16	3
Croatia	9	1	1	10
Denmark	3	2	1	13
Dominican Republic	0	0	0	0
Ecuador	3	11	11	3
Egypt	1	1	12	6
El Salvador	1	3	13	15
Guatemala	9	9	11	11
Haiti	13	16	16	11
Honduras	0	10	10	1
India	6	9	0	9
Jamaica	2	5	5	16
Malaysia	14	2	2	16
New Zealand	0	15	16	14
Pakistan	6	16	16	5
Panama	13	16	16	1
Philippines	9	8	8	10
Sri Lanka	12	0	0	4
Switzerland	1	8	8	15
Trinidad and Tobago	4	16	12	16
United Kingdom	1	1	1	16
United States	1	1	1	1
Venezuela	15	11	11	14

Diagrams iii and iv presents the results for the cointegration test of the two subpanels. The test rejects the null hypothesis of no cointegration for all three variables in both panels.

Diagram iii: High Income Panel Cointegration Tests with Log GDP per Capita

	Group ADF Statistic
Log Total Bank Deposits	-2.509***
Log Total Financial System Deposits	-2.639***
Log Bank Credit to the Private Sector	-2.330***

Note: Symbols denote *10% **5% ***1% rejections

Diagram iv: Low Income Panel Cointegration Tests with Log GDP per Capita

	Group ADF Statistic
Log Total Bank Deposits	-1.789**
Log Total Financial System Deposits	-1.910**
Log Bank Credit to the Private Sector	-2.460***

Note: Symbols denote *10% **5% ***1% rejections

Diagrams v and vi present the country specific causality results for financial system deposits and bank credit to the private sector. The results for bank deposits are depicted as Diagram 5 in the main text.

Diagram v: Individual Member Results in Causality Test for Total Financial System Deposits

	λ_2: f_{it} causing y_{it}			λ_1: y_{it} causing f_{it}			$-\lambda_2 / \lambda_1$
Country	Estimate	Test	P-Value	Estimate	Test	P-Value	Median
Canada	-0.05	-1.80	(-0.07)	-0.28	-2.94	(0.00)	-0.17
Croatia	-0.03	-1.64	(-0.10)	-0.20	-1.84	(-0.07)	-0.16
Denmark	-0.01	-0.50	(-0.62)	-0.21	-2.85	(0.00)	-0.04
Dominican Republic	0.00	0.13	(-0.90)	-0.29	-2.58	(-0.01)	0.01
Ecuador	-0.02	-0.80	(-0.43)	-0.42	-3.62	(0.00)	-0.06
Egypt	0.11	1.31	(-0.19)	-0.34	-2.08	(-0.04)	0.32
El Salvador	-0.01	-0.62	(-0.54)	-0.38	-1.55	(-0.12)	-0.03
Guatemala	0.00	0.19	(-0.85)	-0.12	-1.20	(-0.23)	0.03
Haiti	-0.02	-1.10	(-0.27)	-0.10	-1.70	(-0.09)	-0.19
Honduras	0.05	1.54	(-0.12)	-0.21	-2.08	(-0.04)	0.25
India	0.00	-0.01	(-1.00)	-0.28	-2.29	(-0.02)	0.00
Jamaica	0.03	0.89	(-0.38)	-0.35	-2.82	(0.00)	0.09
Malaysia	0.03	1.08	(-0.28)	-0.12	-1.38	(-0.17)	0.24
New Zealand	0.02	0.92	(-0.36)	-0.18	-2.06	(-0.04)	0.12
Pakistan	-0.04	-2.27	(-0.02)	-0.18	-2.13	(-0.03)	-0.24
Panama	0.00	-0.04	(-0.97)	-0.10	-1.74	(-0.08)	-0.01
Philippines	-0.02	-0.70	(-0.48)	-0.20	-2.71	(-0.01)	-0.08
Sri Lanka	-0.03	-2.67	(-0.01)	-0.07	-1.42	(-0.16)	-0.43
Switzerland	-0.02	-0.75	(-0.45)	-0.26	-2.29	(-0.02)	-0.07
Trinidad and Tobago	-0.17	-3.68	(0.00)	-0.51	-1.33	(-0.18)	-0.32
United Kingdom	-0.01	-0.56	(-0.57)	-0.55	-4.01	(0.00)	-0.02
United States	-0.01	-1.17	(-0.24)	-0.37	-1.64	(-0.10)	-0.04
Venezuela	-0.02	-1.12	(-0.26)	-0.16	-2.15	(-0.03)	-0.13

Diagram vi: Individual Member Results in Causality Test for Log Credit to the Private Sector

	λ_2: f_{it} causing y_{it}			λ_1: y_{it} causing f_{it}			$-\lambda_2 / \lambda_1$
Country	Estimate	Test	P-Value	Estimate	Test	P-Value	Median
Canada	-0.03	-1.18	(-0.24)	-0.37	-3.70	(0.00)	-0.09
Croatia	0.04	1.47	(-0.14)	0.04	0.19	(-0.85)	-0.90
Denmark	-0.01	-0.78	(-0.44)	-0.23	-1.90	(-0.06)	-0.04
Dominican Republic	0.01	0.42	(-0.68)	-0.15	-1.44	(-0.15)	0.06
Ecuador	-0.01	-0.65	(-0.52)	-0.37	-3.13	(0.00)	-0.04
Egypt	0.01	0.19	(-0.85)	-0.28	-2.99	(0.00)	0.02
El Salvador	0.00	0.00	(-1.00)	-0.51	-2.18	(-0.03)	0.00
Guatemala	0.01	0.48	(-0.63)	-0.20	-2.03	(-0.04)	0.04
Haiti	0.00	-0.22	(-0.83)	-0.18	-2.06	(-0.04)	-0.02
Honduras	0.04	1.31	(-0.19)	-0.20	-2.09	(-0.04)	0.19
India	-0.02	-0.77	(-0.44)	-0.23	-2.84	(0.00)	-0.11
Jamaica	0.02	0.75	(-0.45)	-0.44	-2.67	(-0.01)	0.05
Malaysia	0.03	1.17	(-0.24)	-0.03	-0.30	(-0.76)	1.09
New Zealand	0.00	-0.28	(-0.78)	-0.07	-1.60	(-0.11)	-0.03
Pakistan	-0.03	-2.26	(-0.02)	-0.17	-2.28	(-0.02)	-0.18
Panama	-0.01	-0.22	(-0.82)	-0.17	-2.66	(-0.01)	-0.04
Philippines	0.00	0.05	(-0.96)	-0.26	-3.20	(0.00)	0.00
Sri Lanka	-0.04	-2.41	(-0.02)	-0.23	-1.88	(-0.06)	-0.18
Switzerland	-0.01	-0.40	(-0.69)	-0.17	-1.98	(-0.05)	-0.04
Trinidad and Tobago	-0.13	-3.51	(0.00)	-0.30	-0.94	(-0.35)	-0.42
United Kingdom	0.02	1.85	(-0.06)	-0.08	-1.00	(-0.31)	0.25
United States	-0.02	-1.26	(-0.21)	-0.38	-1.60	(-0.11)	-0.04
Venezuela	-0.02	-0.84	(-0.40)	-0.22	-2.06	(-0.04)	-0.07

Finally, Diagram vii presents the results for the test of the sign of causality running from economic growth to each of the financial system variables for the full panel.

Diagram vii: Sign of Causality for y_{it} causing f_{it}

Variable	$-\lambda_1 / \lambda_2$	Standard Error
Total Bank Deposits	1.57	(1.55)
Total Financial System Deposits	1.64	(1.50)
Log Credit to the Private Sector	3.94	(1.92)

Appendix C: RATS Code

This section reproduces the RATS code used to obtain core results. In the interest of relevance and space, the code includes only the adjustment of program options and inputs while excluding the full source code for unit root, cointegration, and causality testing. The "@pancoint" program and corresponding source code can be obtained through the Estima website.

```
*****************************
***Preliminary Data Entry Code***
*****************************

cal(panelobs=48, a) 1960
open data "FINALFALLDATA.xls"                  *Adjusted for Income sub-panels
data(form=xls,org=obs) / LGDPC LBD LFSD LBC

source(noecho) c:\williams\pancoint-modified.src

***********************
***Testing for Unit Roots***
***********************
@pancoint(block=48,mlag=16,tdum) /
#LBD

@pancoint(block=48,mlag=16,tdum) /
#LFSD

@pancoint(block=48,mlag=16,tdum) /
#LBC

@pancoint(block=48,mlag=16,tdum) /
#LGDPC

*************************
***Testing for Cointegration***
*************************
@pancoint(block=48,mlag=10,tdum) /
#LBD LGDPC

@pancoint(block=48,mlag=10,tdum) /
#LFSD LGDPC
```

```
@pancoint(block=48,mlag=10,tdum) /
#LBC LGDPC

**********************
***Testing for Causality***
**********************

* Utilizes "RATS CODE FOR BIVARIATE LONG RUN CAUSALITY TESTS             *
*                 IN HETEROGENEOUS COINTEGRATED PANELS"                   *
*      Author: Peter Pedroni, Williams College, ppedroni@williams.edu    *

*Full text of code excluded: included relevant pieces of input section only

environment noecho


             ***  USER INPUT SECTION ***

compute bootstrap = 1    ;* set to 1 to run bootstrap simulation for group median
compute ndraws = 1000    ;* number of replications desired for bootstrap

compute Nsecs = 23       ;* cross section dimension, N **Adjusted for sub-panels (to 13 and 10)
compute Tperiods = 48    ;* time series dimension, T
                         ;* -see note below for unbalanced panels
allocate 0 Nsecs*Tperiods    ;* set allocate to at least N*T
compute Tdum = 1             ;* set to 1 to subtract time means, else 0
                             **Removes common time effects
compute unbal = 0            ;* set to 1 for unbalanced panel, else 0

open data FINALFALLDATA.xls       ;* read stacked panel data from file
                                  *Adjusted for different sub-panel data files
data(org=obs,format=xls)     ;* one column of length N*T per variable
close data

dec vec[series] datavec(2)
set datavec(1) = LBD;* tel0 ;* egc0 ;*  name of LHS variable in data
                                       **(Change for each)
set datavec(2) = LGDPC        ;* name of first RHS var in data
*set datavec(3) = z        ;* name of second RHS var in data
*set datavec(4) = var4        ;* name of third RHS var in data, etc.

dec vec[label] labelvec(2)
compute labelvec(1) = 'LogBankDeposits'    ;* desired label for LHS variable
compute labelvec(2) = 'gdp'   ;* desired label for first RHS variable
*compute labelvec(3) = 'x2'   ;* desired label for second RHS variable
```

```
*compute labelvec(4) = 'x3'   ;* desired label for third RHS variable, etc.

*************************************************************************
   * (do not change anything below this line for standard run) *

***Remainder of RATS causality code excluded
```

Appendix D: Sources

Bibliography

Aghion, Philippe, and Peter Howitt. (1998). *Endogenous Growth Theory*. Cambridge, Mass.: Massachusetts Institute of Technology.

Aghion, Philippe, and Steven N. Durlauf. (2005). *Handbook of Economic Growth*. Amsterdam: Elsevier.

Bagehot, Walter. (1873). *Lombard Street: A Description of the Money Market*. New York: Scribner, Armstrong & Co.

Barro, Robert J., and Xavier Sala-i-Martin. (2001). *Economic Growth*. Cambridge, Mass.: Massachusetts Institute of Technology.

Barth, James R., Gerard Caprio, and Ross Levine. (2006). *Rethinking Bank Regulation: Till Angels Govern*. New York: Cambridge University Press.

Berthelemy, Jean-Claude and Aristomene Varoudakis. (1996). "Economic Growth, Convergence Clubs, and the Role of Financial Development." *Oxford Economic Paper*, 48(2), 300-328.

Beck, Thorsten, Asli Demirgüç-Kunt and Ross Levine. (2000). "A New Database on Financial Development and Structure." *World Bank Economic Review,* 14, 597-605.

Beck, Thorsten, Asli Demirgüc-Kunt, and Ross Levine. (2009). "Financial Institutions and Markets across Countries and over Time." *The World Bank Policy Research*, Working Paper, May.

Beck, Thorsten, Asli Demirgüc-Kunt, Ross Levine, and Vojislav Maksimovic. (2001). "Financial Structure and Economic Development: Firm, Industry, and Country Evidence," in *Financial Structure and Economic Growth: A Cross-Country Comparison of Banks, Markets, and Development*. Eds. Asli Demirguc-Kunt and Ross Levine. Cambridge, Mass.: Massachusetts Institute of Technology.

Beck, Thorsten, Asli Demirgüc-Kunt, and Vojislav Maksimovic. (2005). "Financial and Legal Constraints to Growth: Does Firm Size Matter." *The Journal of Finance*, 60(1), 137-177.

Beck, Thorsten, Ross Levine, and Norman Loayza. (2000). "Finance and the Sources of Growth." *Journal of Banking and Finance*, 58, 261-300.

Beck, Thorsten and Ross Levine. (2004). "Stock Markets, Banks, and Growth: Panel Evidence." *Journal of Banking and Finance*, 28, 423-442.

Berger, Allen, Asli Demirguc-Kunt, Ross Levine, and Joseph G. Haubrich. (2004). "Bank Concentration and Competition: An Evolution in the Making." *Journal of Money, Credit, and Banking*, 36(3), June, 433-452.

Boulila, Ghazi and Mohamed Trabelsi. (2004). "The Causality Issues in the Finance and Growth Nexus: Empirical Evidence from Middle East and North African Countries." *Review of Middle East Economics and Finance*, 2(2), 123-138.

Boyd, J.H. and E.C. Prescott. (1986). "Financial Intermediary Coalitions". *Journal of Economic Theory*, 38, 211–232.

Christopoulos, Dimitris K. & Tsionas, Efthymios G. (2004). "Financial development and Economic Growth: Evidence from Panel Unit Root and Cointegration Tests." *Journal of Development Economics*, *Elsevier*, 73(1), February, 55-74.

De la Fuente, Angel and J.M. Marin. (1995). “Innovation, 'Bank' Monitoring and Endogenous Development.” *UFAE and IAE Working Papers 307.95, Unitat de Fonaments de l'Anàlisi Econòmica (UAB) and Institut d'Anàlisi Econòmica (CSIC)*.

Demirgüc-Kunt, Asli and Ross Levine. (2001). *Financial Structure and Economic Growth: A Cross-Country Comparison of Banks, Markets, and Development*. Cambridge: The Massachusetts Institute of Technology Press.

Demirgüc-Kunt, Asli and Ross Levine. (2009). “Finance and Inequality: Theory and Evidence.” *Annual Review of Financial Economics*.

Durlauf, Steven. and Paul Johnson. (1995). “Multiple Regimes and Cross Country Growth Behavior.” *Journal of Applied Econometrics*, 10, 365-384.

Enders, Walter. (1996). *RATS Handbook for Econometric Time Series*. New York: Wiley.

Engle, Robert F. and Clive W. J. Granger. (1987). “Co-integration and Error Correction: Representation, Estimation, and Testing.” *Econometrica*, 55(2), 251-276.

Goldsmith, Raymond W. (1969). *Financial Structure and Development*. New Haven: Yale University Press.

Greiner, Alfred, Willi Semmler, and Gang Gong. (2005). *The Forces of Economic Growth: A Time Series Perspective*. Princeton, N.J.: Princeton University Press.

Guiso, Luigi, Paola Sapienza, and Luigi Zingales. (2004). “The Role of Social Capital in Financial Development.” *The American Economic Review*, 94, 526-556.

Kelley, Allen C., Warren C. Sanderson, and Jeffrey G. Williamson. (1983). *Modeling Growing Economies in Equilibrium and Disequilibrium*. Durham, N.C.: Duke University Press.

King, Robert G. and Ross Levine. (1993a). “Finance and Growth: Schumpeter Might Be Right.” *Quarterly Journal of Economics*, 153, August, 717-738.

King, Robert G. and Ross Levine. (1993b). “Financial Intermediation and Economic Development.” Eds. Colin Mayer and Xavier Vives. *Capital Markets and Financial Intermediation*. London: Center for Economic Policy Research, 156-189.

King, Robert G. and Ross Levine. (1994). “Capital Fundamentalism, Economic Development, and Economic Growth.” *The World Bank Policy Research Working Paper*, April.

Koo, Bon Ho, and Dwight Heald Perkins. (1995). *Social Capability and Long-term Economic Growth*. New York: St. Martin's.

Laeven, Luc A., Ross Levine, and Stelios Michalopoulos. (2009). “Financial Innovation and Endogenous Growth.” *CEPR Discussion Paper No. DP7465*. September.

Levine, Ross and Asli Demirguc-Kunt. (2007). “Finance and Opportunity.” *Beyond Transition: The Newletter about Reforming Economies*, 18(2), 5-6.

Levine, Ross and Asli Demirguc-Kunt. (2008a). “Finance and Economic Opportunity.” *Proceedings of the Annual World Bank Bank Conference on Development Economics, Washington, DC*.

Levine, Ross and Asli Demirguc-Kunt. (2008b). “Finance, Financial Sector Policies, and Long-Run Growth.” *Commission on Growth and Development, Working Paper No. 11*, Washington DC: The World Bank.

Levine, Ross. (1997). “Financial Development and Economic Growth: Views and Agenda.” *Journal of Economic Literature*, 35(2).

Levine, Ross. (2003). “More on Finance and Growth: More Finance, More Growth?” *The Federal Reserve Bank of St. Louis*, July/August.

Levine, Ross. (2005). “Finance and Growth: Theory and Evidence.” *Handbook of Economic Growth*. Eds:Philippe Aghion and Steven Durlauf. The Netherlands: Elsevier Science.

Levine, Ross. (2009). “Finance, Growth, and Opportunity: Policy Challenges.” *Brown University and NBER working paper*, October.

Levine, Ross, Thorsten Beck, Asli Demirguc-Kunt, and Luc Laeven. (2008). “Finance, Firm Size, and Growth.” *Journal of Money, Banking, and Finance*, 40(7), 1371-1405.

Levine, Ross and Sara Zervos. (1998). “Stock Markets, Banks, and Economic Growth.” *American Economic Review*, 88(3), 537-558.

Loayza, Norman V. and Romain Ranciere. (2006). “Financial Development, Financial Fragility, and Growth.” *Journal of Money, Credit and Banking*, Blackwell Publishing, 38(4), 1051-1076.

Luintel, Kul B., Mosahid Khan, Philip Arestis and Konstantinos Theodoridis. (2008). “Financial Structure and Economic Growth.” *Journal of Development Economics*, Elsevier, 86(1), 181-200.

Miller, Merton. (1998). “Financial Markets and Economic Growth.” *Journal of Applied Corporate Finance*, 11(3), 8-15.

Pedroni, Peter. (1999). “Critical Values for Cointegration Tests in Heterogeneous Panels with Multiple Regressors.” *Oxford Bulletin of Economics and Statistics*, 61(4), 653-670.

Pedroni, Peter. (2000). “Fully-Modified OLS for Heterogeneous Cointegrated Panels.” *Advances in Econometrics,* 15, 93-130.

Pedroni, Peter. (2004). “Panel Cointegration; Asymptotic and Finite Sample Properties of Pooled Time Series Tests with an Application to the Purchasing Power Parity Hypothesis.” *Econometric Theory*, 20, 597-325.

Pedroni, Peter. (2007). “Social Capital, Barriers to Production and Capital Shares; Implications for the Importance of Parameter Heterogeneity from a Nonstationary Panel Approach.” *Journal of Applied Econometrics*, 22, 429-51.

Pedroni, Peter. (2009). “Empirical Methods for Macroeconomics: Lecture Notes Parts I and II.”

Pedroni, Peter and David Canning. (2008). “Infrastructure, Long Run Economic Growth and Causality Tests for Cointegrated Panels.” *The Manchester School*, 76(5), 504-527.

Phillips, Peter C.B. (1998). “Impulse Response and Forecast Error Variance Asymptotics in Nonstationary VAR’s.” *Journal of Econometrics*, 83, 21-56.

Rajan, Raghuram G. and Luigi Zingales. (1998). “Financial Dependence and Growth.” *American Economic Review*, 88(3), 559-586.

Robinson, Joan. (1962). *Essays in The Theory of Economic Growth.* London: Macmillan.

Robinson, Joan. (1952). “The Generalization of the General Theory.” *The Rate of Interest, and Other Essays*. London: Macmillan, 67-142.

Ros, Jaime. (2000). *Development Theory and the Economics of Growth*. Ann Arbor: University of Michigan.

Rousseau, Peter L. (2003). “Historical Perspectives on Financial Development and Economic Growth.” *The Federal Reserve Bank of St. Louis*, July/August.

Rousseau, Peter L. and Paul Wachtel. (2000). “Equity Markets and Growth: Cross-Country Evidence on Timing and Outcomes, 1980-1995.” *Journal of Banking and Finance*, 24(12), 1933-1957.

Rousseau, Peter L. and Paul Wachtel. (2002). “Inflation Thresholds and the Finance-Growth Nexus.” *Journal of International Money and Finance*. (21), 777-93.

Rousseau, Peter L. and Paul Wachtel. (2008). “What is happening to the Impact of Financial Deepening on Economic Growth?” *Extension on WIDER Discussion paper DP2005/10*, January.

Schumpeter, Joseph A. (1911). *The Theory of Economic Development: An Inquiry into Profits, Capital, Interest, and the Business Cycle*. Cambridge: Harvard University Press.

Valdés, Benigno. (1999). *Economic Growth: Theory, Empirics and Policy*. Cheltenham, UK: Edward Elgar.

Wachtel, Paul. (2003). “How Much Do We Know About Growth and Finance?” *Federal Reserve Bank of Atlanta, Economic Review*, First Quarter.