A MODEL OF SCHUMPETERIAN GROWTH WITH INSTITUTIONAL CHANGE AND FINANCIAL DEVELOPMENT: THEORY AND EVIDENCE

DISSERTATION

Presented in Partial Fulfillment of the Requirements for

the Degree Doctor of Philosophy in the Graduate

School of The Ohio State University

By

Peter J. Kower, M.I.M, M.A

*****

The Ohio State University
2002

Dissertation Committee:

Professor Claudio Gonzalez-Vega, Advisor

Professor Peter Howitt

Professor Ian M. Sheldon

Approved By

Advisor
Department of Agricultural, Environmental and Development Economics

ABSTRACT

This dissertation investigates the role of endogenous industrial innovation and institutional change in the achievement of modern economic growth. A model of Schumpeterian growth is combined with key elements of Northian theory of institutional innovation, as proxied by financial sector development. In this framework, a set of purposeful entrepreneurs will undertake costly and uncertain research and development (R&D) in order to create a blueprint for a drastically better intermediate good. Given the plausible assumption of private information concerning the uncertain arrival of an innovation, market frictions arise naturally in the Arrow-Debreu environment underlying this model. The resulting transaction costs associated with funding R&D provide profitable opportunities for entrepreneurs to innovate financial institutional arrangements. Fixed-effects panel regression results show that both R&D intensity and institutional change are important determinants of cross-country per capita income differences.

DEDICATION

To my wife, Joanie: for her encouragement to follow my heart,

for her support and unwavering faith in me,

for her kind humor and delight in all things great and small,

for the many missed hikes and nights under the stars,

for reminding me what is truly important in life,

and most of all for her friendship and her love.

To Mark and David and the Men of Thursday Nights: words fail me.

And

In loving memory of our dear friend Debbie - you are forever in our hearts.

ACKNOWLEDGMENTS

I wish to thank my advisor, Claudio Gonzalez-Vega, for providing the opportunity to pursue my doctoral studies and for helping shape the direction and focus of my research. I am very grateful to Peter Howitt for his time and generosity in leading me through the intricacies and wonders of growth economics. His many suggestions and kind support, even from afar, are greatly appreciated and will be long remembered.

Ian Sheldon's comments have always been thoughtful, kind, and occasionally quite humorous. I have benefited greatly from interactions with many other faculty members, including Mario Cruccini, Doug Graham, Dave Kraybill, Naci Mocan, James Peck, and Richard Steckel, who introduced me to the writings of economic history. I would not have been able to write this page, had it not been for the on-going discussions, useful comments, support, and wonderful friendship of Alka Gandhi, Roisin O'Sullivan, and Maria Pagura, my comrades in arms. I had the good fortune to work for Elliot Slotnick at the Graduate School and wish to thank him for his many kindnesses, his words of advise, and encouragement. And to my many classmates and co-workers, who shared the journey and enhanced the experience, thank you.

VITA

July 14, 1957 ……………..……………..…….Born - Chicago, Illinois

December, 1979 …..………..…………………BA History, Arizona State University

May, 1982 …..……………..…………………….M.I.M. International Management,
American Graduate School of
International Management

1983-1985 …..….……………………………….Vice President, Security Pacific Bank -
Market Information - New York

1986-1987 …….…….………………………..…Partner, Mentor Information Services

1988-1992 …….…….…………………………Associate, Park Group – Phoenix, AZ

1992-1996….…………….…….……………Lecturer, Community College of Aurora

May, 1996………………..………………….....MA Economics, University of
Colorado at Denver

1996-1998……………………………………Fellow and Graduate Teaching Associate
Economics, The Ohio State University

1998-2002………………………………......Agricultural, Environmental, and
Development Economics
The Ohio State University

FIELDS OF STUDY

Major Field: Agricultural, Environmental, and Development Economics

Specialization: Growth and Development, Finance, and Economic History

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

The goal of this dissertation is to extend the investigation into the complex causes of modern economic growth, as characterized by a country's ability to achieve sustained increases in per capita income over an extended period. Its specific focus comes from economic historians' analysis of the roles played by technological progress and institutional development in the relatively recent achievement of long-run growth by western countries.

A broad segment of the economic history literature emphasizes the importance of innovation and technological progress in the achievement of sustained economic growth.[1] Technological progress is defined as an increase in man's knowledge about the physical world and the application of this knowledge to productive purposes. Schumpeter's (1934) theory of purposeful innovation, as formalized by Aghion and Howitt (1992, 1998a), serves as the basis for the formal model developed in this dissertation.

[1] For example, see Schumpeter (1934,1942), Rosenberg (1982), North (1981), and Mokyr (1990).

Schumpeter, writing in the first part of the previous century, concludes that the underlying dynamic force of capitalism stems from competition among rival entrepreneurs to develop new processes or products. In this theory of innovation-based growth, a purposeful agent will expend real resources in order to create a blueprint or "new combinations" of inputs necessary to produce an existing product at a lower cost or, more importantly, to develop an entirely new product.

Rosenberg (1982), in discussing Schumpeter's theory of creative destruction, states that it was not the increasingly efficient production of harnesses that ultimately accounted for the revolution in transportation; rather, it was the creation of drastically new and unforeseen modes of transport, e.g., the railroad or the automobile, that was responsible for this revolution. Thus, in this framework it is assumed that each new productive idea or blueprint leads to such a sufficiently superior product and that, through the threat of Bertrand price competition, the successful entrepreneur completely displaces the incumbent firm or agent. This specification implies that, in each industrial intermediate goods sector, a successful innovation allows the entrepreneur an opportunity to earn monopoly rents, at least until she, in turn, is replaced by the next innovator in her industrial sector. It is this dynamic process of purposeful innovation, followed by "gales of creative destruction," that Schumpeter contends is responsible for economic growth.

Turning to the role of institutional development in economic growth, North (1991) states that, "… institutions have been devised by human beings to create order and reduce uncertainty in exchange. Institutions provide the incentive structure of an economy; as the structure evolves, it shapes the direction of economic change towards growth, stagnation, or decline." (p. 239).

Despite the posited importance of institutions in growth, Aghion and Howitt (1998a) conclude that still one of the major limitations associated with the recent endogenous growth literature, "… is the lack of attention to *institutions and transaction costs*." (p. 66). The Arrow-Debreu framework, underlying recent growth models, abstracts completely from the existence of market frictions or other impediments to trade, which leaves little or no economic justification for the existence and development of costly institutions. This inattention in the growth literature to change in institutional arrangements has led to both theoretical and empirical model misspecification, as will be discussed below.[2]

The potential for institutions to be important in the Schumpeter-Aghion-Howitt framework arises naturally. The outcome of costly research and development (R&D) is fundamentally uncertain. The arrival of a new innovation is modeled here as a

---

[2]North (1981) states, "From the viewpoint of the economic historian, this neoclassical formulation appears to beg all the interesting questions." (p. 5).

stochastic process dependent on both the quantity and quality of resources employed by the entrepreneur. Following Townsend (1979), the model assumes the existence of private information in the R&D sector. The stochastic arrival of a new industrial blueprint is known only to the entrepreneur. In order to receive funding for industrial R&D, entrepreneurs must be willing to pay a fee for costly monitoring or state verification.[3] This, in turn, will provide profitable opportunities for new entrepreneurs to turn their attention to innovation of institutional arrangements in the financial sector, given the existing institutional superstructure or environment.

Davis and North (1971) define the institutional environment as the set of fundamental laws, structures, and norms that establish the "rules of the game." Such rules are most generally associated with the creation, definition, and enforcement of property rights. In order to analyze purposeful institutional innovation, these authors posit that the underlying institutional environment is exogenous and that, given this environment, *Schumpeterian* entrepreneurs have incentives to spend real resources to create a blueprint for new institutional arrangements and associated instruments.

---

[3] The role of finance in overcoming private information represents a very parsimonious model specification. King and Levine (1993b) state that financial development spurs deposit mobilization, pools and diversifies risk, reduces transaction costs associated with information asymmetries, and ensures the efficient allocation of savings. Also see Shaw (1973) and McKinnon (1973) for the broader impact of financial development in lagging or fragmented economies associated with LDCs.

To demonstrate the positive link between institutional change and economic growth, the authors cite, among other examples, the influence of new institutional arrangements in the financial sector of the United States since the beginning of the 19th century.[4] American financial sector innovations, from the development of a national money market to the creation of markets for highly specialized securities, lowered transaction costs associated with asymmetric information and provided an ability to pool and diversify risk associated with undertaking new projects.

Under the status quo, any profits available from the reduction of financial transaction costs can not be fully captured by agents, but rather require the innovation of a new arrangement, which may be accompanied by new financial firms and instruments. Two other potential sources of profits from institutional change, described by North and Davis (1971), increasing return economies and those associated with overcoming capital indivisibility, are not necessary for the development of the model in this dissertation.

In order to incorporate the key elements of Northian endogenous institutional change, this dissertation focuses on purposeful innovation of institutional arrangements associated with the emergence and, more importantly, the development of the financial

---

[4] According to the authors, causality runs in both directions. For example, the introduction of life

sector. Financial development is narrowly defined here as the ability of the financial system to overcome market frictions associated with the funding of the creation of new blueprints or ideas. Analytically, financial development is defined to be the inverse of one plus the proportional financial transaction costs, (τ).[5]

To further explore the role of finance and R&D in growth, the model makes the assumption that there is no uncertainty and therefore no related transaction costs in the market for capital, and that this competitive market, in equilibrium, clears at a price that is equal to the marginal revenue product of capital in the aggregate production function. Because of the complementarity between capital accumulation and R&D expenditures in long-run growth (Aghion and Howitt, 1998b), introducing uncertainty in the capital market would further strengthen the link between financial sector development and increased R&D levels and, ultimately, economic growth. The model assumes that financial claims associated with entrepreneurial activities represent the marginal asset of the financial sector.[6]

Exclusive focus in this dissertation on financial sector change and innovation, given the

variety of observed institutional arrangements in the world, is justified by the unique

---

insurance awaited developments in applied mathematics necessary to form actuarial tables.

[5] This transaction costs, $\tau \in [0, \infty)$, can be thought of as the difference between the loan rate paid by deficit units (borrowers) and the deposit rate received by surplus units (savers) for bank loans. This definition comes from the development finance literature; see Gonzalez-Vega (1984).

characteristics of financial contracts, which represent a promise to pay at some future date in exchange for control over resources in the present. The intangible, contingent and intertemporal nature of trade in financial markets make this sector's transactions and institutional arrangements most dependent on the state of the existing institutional environment. In this respect, the development of the financial sector can be viewed as the bellwether for the general level of institutional knowledge in a society.

Several earlier studies support this view. Clague et al. (1999) posit that the increase in contract-intensive money (M2 less currency holdings) serves as an objective measure of a nation's ability to define property rights and to enforce contracts. Benhabib and Spiegel (2000) employ a panel regression model to empirically test for the role of finance in growth and conclude that measures of financial market development are not robust to the inclusion of country-specific fixed effects. Thus, these authors conclude that the significance of financial measures must be capturing an unobserved variable, such as the level of property rights.

To the extent that North (1989) is correct about the Solow residual representing changes in human organization, King and Levine's (1993a,b) seminal findings that growth in total factor productivity (TFP) and the size of formal financial

---

[6] Bodenhorn's (1999) discussion of the lending behavior of a newly formed "Free Banking Era" bank in the 1840s in New York state underscores this point. It was banking's ultimate inability to fund marginal R&D projects that lead to innovation of specialized arrangements, e.g., venture capitalists.

intermediation are positively correlated support the plausibility of finance as a measure of overall institutional development. Finally, Levine, Beck, and Loayza (2000) conclude that the exogenous portion of financial development, as captured by the origin or specific aspects of a country's legal system, e.g., shareholder versus credit rights, "cause" economic growth, as measured by the growth rate of per capita income.

In addition to Schumpeter (1934) and North and Davis (1971), a significant body of literature exists, dating from at least Adam Smith, that posits an important role for money and finance in economic growth. According to Mokyr (1990), Smithian growth stems from an increase in market size that allows greater division of labor and additional opportunities for specialization. However, to achieve the full gains from trade requires the use of a medium of exchange that would reduce transaction costs associated with search and barter. Following Smith's logic, Gurley and Shaw (1955) make a compelling, if not formal, case for including financial market development in considerations of long-run growth. These authors assert that movement away from financial autarky to bank intermediation plays a critical role in improving the allocation of scarce savings to the (socially) highest return projects. Subsequent innovative uses of savings, however, require further development of the financial sector itself, e.g., development of non-banking intermediaries and other financial markets.

Recent theoretical contributions that exploit advances in the theory of asymmetric information to motivate the emergence of financial intermediaries can be viewed as attempts to formalize Gurley and Shaw (1955).[7] Such works include Diamond (1984), Prescott and Boyd (1986), Greenwood and Jovanovic (1990), Bencivenga and Smith (1991, 1998), King and Levine (1993b), and Boyd and Smith (1998). Bencivenga, Smith, and Starr (1995) discuss the emergence of equity markets and their provision of liquidity (insurance). However, Holmstrom and Tirole's (1993) theory, linking equity market liquidity to improved agent monitoring is more consistent with the information structure of the dissertation's model. A fuller discussion of these papers is presented in the following chapter.

These contributions have been successful in demonstrating the benefits of the initial emergence of financial intermediaries in economies (i.e., the problem of existence) but fail to fully investigate the impact of further financial sector development on sustained growth.[8] In other words, the recent theoretical literature has not explicitly modeled change in the financial sector as a dynamic process in economic growth. In turn, empirical investigations have treated financial development in a fundamentally static way, employing the assumption that over time financial services providers utilize the

---

[7] A rich literature that formalizes the Gurley-Shaw-McKinnon view without relying solely on information adds depth to our understanding of finance. Fry (1988) provides a useful summary of the key contributions made this tradition.

[8] Additionally, these contributions have relied on early endogenous growth models to explain finance's ability to impact sustained growth. There are several counter-factual implications inherent in

same production technology.[9] Increases in the aggregate allocative efficiency of an economy are brought on by the expansion of existing concerns and through the entry of additional but identical firms into the sector.

Another factor which may have slowed consideration of institutional development in growth models is the emphasis on total factor productivity (TFP) as the primary measure of technical progress. In his seminal work on economic growth, Solow (1956) concludes that, due to diminishing returns, capital accumulation alone can not be responsible for a positive growth rate in the steady state. However, sustained growth would be possible if societies experience increases in productivity stemming from external technical progress. This view assumes that all countries have equal access to the underlying knowledge responsible for the technical gains. The Solow residual or TFP is calculated using a standard neoclassic Cobb-Douglas production function. Given the share of capital in income, the residual is calculated by subtracting the rate of capital accumulation and the rate of growth of the working age-population from the growth rate in output.[10]

---

these models; see Jones (1995). The major exception is King and Levine (1993b), who employ an early (labor-only) Schumpeterian model of growth.

[9] In addition to King and Levine (1993a,b), these empirical contributions include Levine and Zervos (1998), Rousseau (1998), and Levine, Beck, and Loayza (2000).

[10] The share of physical capital in income is usually assumed to be about 1/3 for this purpose. See Mankiw (1995) and Hall and Jones (1996). This assumption does not seem well founded.

DeLong (1996) contends that the emphasis on this residual and its use to proxy technical progress has adversely affected the way in which researchers approach growth questions. According to DeLong, TFP is a very poor measure of technical progress, in the sense of the creation of the internal combustion engine or other industrial innovations.[11] North (1989) contends that, in fact, much of the Solow residual is due to improved human organization and not to man's increased control over nature, i.e., technical progress. Growth regressions that employ TFP as a proxy for technologically induced productivity changes may be misguided.

In the Schumpeter-Aghion-Howitt framework, endogenous technological progress is due to innovation of a new productive idea created by profit-seeking entrepreneurs. Empirical growth studies based on this framework and on Grossman and Helpman (1991) have used real expenditures on research and development (R&D) to proxy entrepreneurial activity and thus productivity.[12]

By explicitly controlling for institutional change, the model developed below provides an ability to more clearly study innovation, productivity, and growth. Following directly from the formal model, the dissertation's empirical model improves on the current specification of cross-country growth regressions.

---

[11] DeLong contends that the Solow residual more likely captures sectoral shifts associated with movement out of agriculture and with demographic changes.

[12] Zacharaides (2000) posits that R&D impact on growth follows a sequential path from R&D to patent creation, to change in productivity (TFP), to increases in per capita output. He concludes that the full impact of R&D on growth may take five years or longer. See discussion of this feature of innovation in Chapter 6.

Regressions that do not simultaneously control for both innovation and institutional change may lead to biased and inconsistent estimates. For example, Bassanini et al. (2000) present an empirical study that includes R&D intensity as an explanatory variable in a single regression model but without measures associated with financial depth and visa versa. Levine et al. (2000) focuses on financial depth's importance in explaining cross-country differences in per capita income growth, but they do not explicitly control for technical change or differing levels of productivity.

Old - New Stylized Facts of Modern Growth

In a study of western countries from 1820 to 1989, Madison (1991) states, "The most striking characteristic of capitalist performance has been the sustained upward thrust in productivity and real income per head, which was achieved by a combination of innovation and accumulation." (p 5).[13] According to the author, over the period, the average annual growth rate in per capita income was 1.6 percent, which compares with rough estimates of 0.2 percent in the preceding several centuries, the proto-capitalist period. Mokyr (1990) discusses technological advances in medieval Europe, while North (1982) covers institutional advances. Avoiding specific discussion here of the timing and meaning of the Industrial Revolution, growth rates

[13] Madison (1991) includes the following countries: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, Norway, Sweden, Switzerland, UK, and US. Note that Japan is a late entrant in the group of "western countries"

experienced after 1820 represent a marked improvement in the material well being of the inhabitants of the western countries in Madison's study.

Evans (1996) indicates that the variance of the growth rate of the countries in Madison's sample showed no tendency to increase in the post-war period. This result can be interpreted to mean that these countries have grown at a similar rate over the period or that these countries are converging to parallel growth paths. Investigating growth patterns for a large number of countries in the post-war period, Quah (1996, 1997) finds the emergence of "twin peaks" or the observation that most countries have clustered around one of two distinct income levels. The insights of Evans (1996) and Quah (1996) form the basis for the stylized fact of "club convergence", in contrast to the conditional convergence predicted by neoclassical models.

Howitt (2000) contends that countries that have the proper incentives to foster R&D will be able to achieve sustained positive growth rates in the steady state, while the remainder of non-innovating countries will stagnate.[14] According to Howitt, the convergence of OECD countries to parallel growth paths is based on the existence of the spillover of knowledge related to innovation of new industrial ideas.[15] The existence of inter-country knowledge spillovers is presented by Coe and Helpman (1995) and Eaton and Kortum (1999). The latter work is of note because it finds that

---

[14] This implication of the dissertation's model begs the very interesting and important question of how countries have been able to leave the stagnate club to join the growth club, e.g. the Korean growth experience.

[15] OECD member countries are Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Italy, Ireland, Japan, Portugal, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, UK, and US.

the majority of patenting activity, both patenting in the home country of the innovation and in foreign countries, is highly concentrated in the US, Japan, Germany, UK, and France.

As long noted by economic historians of technical progress (e.g., Rosenberg 1982), the creation of a new idea generates externalities across firms, industries, and national borders. The underlying idea behind each technological breakthrough is non-rival and only partially excludable; it can be used by a different entrepreneur in attempting to create a new blueprint in other sectors of a society or in other countries. But unlike the neoclassical growth model employed by Mankiw, Romer, and Weil (1992), the diffusion of a new idea is neither simultaneous nor without cost. Countries that lack the proper institutional framework and do not undertake costly R&D will be unable to exploit positive externalities inherent in the production of new ideas elsewhere and will be unable to achieve modern growth.

Early endogenous growth models, for instance the AK model, in which capital accumulation does not suffer from diminishing returns, implies that leader countries could not be caught from behind.[16] That is, under the assumption of this early endogenous growth model, there is absolute divergence in growth paths and a potential for explosive growth. In contrast, in the Schumpeter-Aghion-Howitt model,

---

[16] The general form of the aggregate production function is $Y_t = A_t K_t$, where *A* is the productivity parameter and *K* represents capital, broadly defined.

growth rates in leader countries will slow as they approach the steady state from below. The leader or most technologically advanced country has, by definition, a greater number of industrial sectors that have experienced recent innovation. Each sector's level of productivity is relatively close to the world's leading-edge value. A sector-specific innovation adds to the aggregate stock of knowledge in the world, albeit, marginally. Leading countries will gain only incrementally from spillovers associated with the next innovation developed elsewhere. In contrast, countries with relatively few industrial sectors with recent innovations will benefit considerably from cross-country spillovers and achievement of a domestic breakthrough will significantly raise the average productivity level. Technological transfers thus allow lagging countries a chance for catch-up and, over time, countries that engage in R&D will converge to a common growth rate.

An equally important characteristic of growth in the post-war period is discussed by Hall and Jones (1996), who find that, even among advanced countries, large differences remain in both per capita income and productivity. Standard neoclassic theory is unable to successfully explain the combination of these observations. One of the major criticisms of Mankiw, Romer, and Weil's (1992) empirical test of the augmented-Solow model concerns its main identifying assumption that each country in a broad sample has a common productivity parameter. In contrast, innovation-based models of growth are consistent with the initial formation of groupings of countries that share a common growth rate. Even within a growth club, countries have different productivity levels and per capita income in the steady state.

Testable Hypotheses

This dissertation extends the Aghion-Howitt model by including consideration of endogenous institutional change. The first testable hypothesis posits that, after controlling for institutional change, endogenous productivity differences, as captured by R&D intensity, should explain a significant portion of the differences in per capita income, even within a group of similar countries, such as countries in the OECD.

Several studies find that R&D expenditures, at the firm and industry level, have substantial impact on output levels. For a survey of early contributions to this literature see Nardiri (1993). To my knowledge, few studies have been undertaken to establish the importance of endogenous R&D in determining the level of cross-country per capita income and to assess the convergence behavior of countries over an extend period.[17] These few studies, furthermore, lack sufficient theoretical underpinnings and suffer from a variety of empirical problems, including omitted variable bias, simultaneity bias, and non-spherical error terms. In contrast, the dissertation's

[17] Nonneman and Vanhoudt (1996) extend the Solow framework by including R&D as a capital input in production, which is not theoretically sound and leads to improper calculation of structural parameters. Their calculated value (0.084) for the income elasticity of R&D intensity is less than one-half of the value derived below. See the second regression output in Table 3.1.

theoretical model leads to a well specified regression equation. Improving on the empirical shortcomings of previous work, the regression results support the Schumpeterian view of economic growth.

Second, the model developed in this dissertation implies that the development of institutional arrangements associated with financial markets should positively impact cross-country differences in R&D intensity, the proximate cause of economic growth. Better financial markets lower the amount of scarce resources necessary to overcome asymmetric information associated with funding the uncertain and private creation of a new industrial blueprint.

Given the assumptions of the model, however, finance should have only a small, if any, direct effect on per capita income differences. The presence of the financial variable in the primary regression equation of the empirical model should help avoid problems associated with omitted variables or misspecification.[18]

In order to test the hypotheses derived in the model, a sample of OECD countries is employed. The motivation for selection of this sample follows below. The sample period is 1971 to 1995, rather than the 1960 to 1985 sample period employed in Mankiw, Romer, and Weil's (1992) seminal work. The more recent sample period

[18] The primary regression equation, a Schumpeterian version of the Solow or neoclassic empirical model augmented with an aggregate measure of financial market efficiency, is developed in the last section of Chapter 3.

allows for the use of new data associated with financial development and R&D expenditures. Following recent growth studies, first, a simple cross-section regression is run using the average values for the full sample period. While there are limitations to this method, the results should provide insight into long-term impacts of R&D and of finance on economic growth, which may not be captured over shorter time periods.

A second set of results is produced by extending the cross-sectional data over time. The data is averaged over five-year periods, and panel regression techniques are employed. Finally, because of the complexity and interrelated nature of economic growth, these regressions will incorporate corrective measures for the existence of endogenous right-hand-side (RHS) variables, namely two- and three-stage least squares regressions are run. This method provides a means to correct for the simultaneous biased noted above. Following Mankiw, Romer, and Weil (1992) and Mankiw (1995), the economic performance of OECD countries in the post-war period is assumed to represent out-of-steady state growth patterns. Thus, the initial values of per capita GDP are included in the main regression equation, which should provide a more rigorous test of R&D's role in growth than steady state configurations would.[19]

---

[19] Also, steady state regressions are run without the initial value of per capita income. The results strongly support the view that, in the steady state, cross-country differences in per capita income are greatly influenced by R&D intensity.

The tradition of the growth literature of using large samples of disparate countries to test growth theories has been criticized by Brock and Durlauf (2000), among other issues, for sample heterogeneity. The interpretation of the value of a coefficient associated with an explanatory variable (e.g., human capital) can not possibly capture the structural characteristics of any individual countries in the sample. Thus according to these authors, policy recommendations are not feasible based on the results from these broad cross-country regressions.

To avoid problems associated with sample heterogeneity, I begin with Mankiw, Romer, and Weil's (1992) intermediate 72 country sample, which eliminated countries with poor data quality from the original Summers and Heston's (1991) data set. This sample is further divided into countries with membership in the OECD in 1960 versus non-OECD member countries. To test the robustness of the full OECD country sample (less Ireland and Turkey), the dissertation further divides OECD countries into two groups as determined by statistical methods based on a high dimension of initial conditions and country specific characteristics.[20] See Desdoigts (1999) for further details.

Summary of Findings

[20] Group I countries are Belgium, Canada, Denmark, Finland, Japan, Netherlands, Norway, United Kingdom, and United States.

In a review of recent empirical studies of growth differences across countries, Ahn and Hemming (2000) state, “The greatest problem underlying the use of cross-country regressions is the lack of accepted theoretical models that can accommodate the wide range of variables that are often included as explanatory variables.” (p. 6). The augmented Schumpeter-Aghion-Howitt formal model leads to a very sparse empirical specification, which is used in this dissertation to test for the ability of R&D and institutional development, as captured by financial development, to help explain modern economic growth. The Schumpeter-Aghion-Howitt model augmented with Northian institutional change is tested using both cross-section and panel data techniques.

The initial cross-section regression, following the tradition of the early empirical growth literature, uses the average value of the data over the entire 25-year sample period, 1971-1995. The results support the underlying Schumpeterian theory of R&D-led growth. In the primary equation, in which per capita income is the dependent variable, the coefficient on the R&D variable is both positive and significant in the steady state and out-of-steady state model specifications. The latter specification includes the initial level of per capita income, which controls for the impact of individual country convergence to its steady state growth path, to reflect the transitional dynamics of most OECD countries in the post-war period.[21]

[21] The coefficient associated with initial income has been interpreted as a measure of the speed of convergence. Convergence rates here range from approximately 2.0 to 3.0 percent per annum, which is in line with previous estimates.

The use of a system of equations to control for the presence of endogenous or jointly-determined variables, R&D and financial development as regressors in the primary equation, provides a means to test for the role of finance in the determination of the level of R&D intensity across countries. Endogenous financial development, as captured by a measure of the efficiency of the banking system, helps to explain cross-country differences in the level of R&D intensity.

The three-stage least squares (TSLS) regression technique is used to perform the empirical test. This method requires the deployment of two additional regression equations, one for each of the two endogenous regressors. While two-stage least squares regressions are often employed, the third stage, based on a seemingly unrelated regression (SUR), is run to control for the posited contemporaneous correlation of the error term of each of the three equations in the system. The correlation stems from North and Davis' (1971) assumption that the institutional superstructure is exogenous. Shocks to this institutional environment (e.g., revolution, coup, or broad legislative reform) impact each of the processes that determine the model's critical endogenous variables, per capita income, R&D intensity, and financial development.

The empirical results provide evidence that the flow of real resources into R&D, normalized by GDP, a well recognized proxy of innovation or technological progress, explains differences in per capita income across similar countries, after controlling for broad capital accumulation (Solowian growth) and endogenous institutional change (Northian growth), as captured by financial development. The estimated structural parameter associated with R&D intensity in the primary regression equation ranges from 0.18 to 0.31. In the neoclassic context, this parameter could be thought of as R&D investment's "share" of national income.

The magnitude of the R&D parameter compares favorably to the estimated share of physical and human capital investment in the augmented-Solow neoclassic equation presented in Mankiw, Romer, and Weil (1992). These authors report that the combination of the two investment parameters is equal to 0.39 for OECD countries over the 1960-1985 period. After controlling for R&D and financial development, the sum of these parameter values drops to 0.25. However, given the numerous empirical shortcomings associated with the regression, this estimated value should be used as an upper bound.[22]

Financial development fosters increased R&D; therefore, after controlling for R&D flows and capital flows in this regression equation, the finance variable should not be significant in directly explaining per capita income differences.[23] Rather, in the

---

[22] For example, the assumption of a single productivity level across all countries leads to an omitted variable bias, which can inflate the capital parameter values. See McGrattan and Schmitz (1998) and Howitt (2000) for additional details.

[23] As will be discussed in Chapter 2, the literature on the finance growth nexus posits two major channels for improved financial services, increased capital accumulation and efficiency improvements. See Beck and Levine (2000) for a discussion that emphasizes the later channel.

second equation in the TSLS system, one in which R&D is the dependent variable, the coefficient on the financial variable should be positive and economically significant. The growth process is complex, posited causes are highly interdependent and institutional or non-technical productivity is important, according to these findings.[24]

[24] Clague et al. (1999) assert that simple measures of financial intermediation, e.g., M2 less currency holdings are highly correlated with subjective measures associated with the rule of law, corruption, and political freedoms. Also see Levine's (1997) discussion of law and finance.

CHAPTER 2

FINANCIAL MARKET DEVELOPMENT

Towards a Theory of Finance in Growth

Gurley and Shaw (1955) posit that the initial emergence of primitive bank-intermediaries will allow societies to move away from financial autarky, increasing the return on savings, as high yielding projects are identified and funded. In this initial phase of financial development, a payments or monetary system emerges, savings volumes increase, and resources are moved from wasteful or non-productive asset holdings and low return projects to socially high returning projects. Thus, the improved resource allocation associated with a growing financial sector allows an economy to achieve aggregate allocative efficiency. The resulting increases in income provide additional savings for further financial expansion.

According to Gurley and Shaw, more innovative uses of savings are only made possible by the next wave of financial innovations, which may include development of non-bank intermediaries, which issue new financial liabilities, as well as the expansion of equity and other markets that trade financial claims. The basic idea that the initial emergence of financial markets leads to the improved allocation of scarce savings forms a common theme in the subsequent theoretical literature, although the exact information structures employed as well as the mechanisms of how improved flows of funds impact growth vary widely.

Development of a more dynamic treatment of Gurley and Shaw (1955) leads to consideration of Shaw (1973) and McKinnon (1973). Both contend that “lagging” performance of many developing countries (LDCs) during the post-war, trade-led economic boom was due, in large measure, to the financial repression associated with misguided development policies, e.g., import substitution strategies. Financial repression is marked by interest rate ceilings, high inflation or monetary tax, high reserve requirements, targeted and/or subsidized credit, and other financial market distortions. Under such regimes, real returns on financial assets are often negative and financial markets are “shallow” or non-existent. Shaw (1973) contends that a change in policy leading to financial liberalization not only increases the size of the financial market, as measured by society’s money holdings but, more importantly, it provides profitable opportunities for new firms to enter the financial sector.

Based on this view, many of the subsequent researchers have defined financial sector development solely on Shaw’s definition of financial “deepening”, as the size of the market for intermediated funds, while failing to model the impact of innovations in the sector. In this dissertation, the financial sector is explicitly modeled as a purposeful dynamic Schumpeterian process. Thus, financial development refers to the ability of the sector to innovate institutional arrangements, organizations, and instruments to better overcome market frictions associated with asymmetric information. These innovations lower transaction costs of financing industrial entrepreneurs. The level of financial repression is modeled here as a "tax" on the production of financial services.

McKinnon (1973) posits that repressive development policies further fragment nascent national or regional markets in LDCs. The lack of well-integrated regional and national markets, especially in the case of intertemporal trade, leaves agents isolated and dependent on limited trading opportunities. The local or fragmented financial market is unable to get the "price right"; interest rates differ widely across each small localized market and do not correctly reflect the true scarcity of savings nor the relative price of inputs or final goods at the national level. The Gurley-Shaw-McKinnon synthesis is best captured as a Schumpeterian endogenous process which controls specifically for financial repression.

Private Information: A General Equilibrium Rationale for Finance

Delay in extending the basic theory of Gurley and Shaw (1955) may have been due to the development and wide acceptance of the Solow model, which concludes that the steady state growth rate of a country is independent of changes in the capital stock. That is, economic growth is ultimately determined by the rate of exogenous (unexplained) technological progress and by the exogenous rate of population growth. The wide use of the general equilibrium framework of Arrow-Debreu slowed consideration of the importance of institutions, in general, and of innovation of financial institutional arrangements, specifically. Given the assumption of complete contingent markets and perfect information in Arrow-Debreu, there exist no impediments to trade nor accompanying transaction costs in the economy. Therefore, no theoretical justification for the emergence of costly institutions in a market economy can be made.

For the purposes of this dissertation, the existence of market frictions stemming from information asymmetries is based on Townsend (1979). This author demonstrates that, in a simple exchange economy, with uncertainty over the realization of an agent's next period endowment, when combined with the existence of private information concerning this event, leads to transaction costs, which hinder or destroy trade. Townsend posits that the optimal contract for securing the benefits of trade will take the form of a bond or debt instrument and will require incentive compatible agreements that induce costly state verification in the event of default by the borrower. Inter-temporal trade of next period's endowment between two agents will be Pareto improving given the assumptions of Townsend's model.

Using a similar environment, Diamond (1984) posits that, in a given society, a coalition of agents will form and specialize in financial intermediation to perform costly monitoring of borrowing agents. In order to incorporate development of equity financing as a mechanism for lower monitoring costs, Holmstrom and Tirole (1993) is applied here. These authors show that liquid equity markets provide important monitoring services given the asymmetries between owners and delegated managers.

Although the model developed in the next section uses an alternative informational structure, the following works have made significant contributions to our understanding of finance and growth. Boyd and Prescott (1986) contend that the existence of private information over the type of investment project (or agent) will lead to the development of coalitions to evaluate, fund, and monitor "good" projects. Greenwood and Jovanovic (1990) posit that the allocation of savings to better projects is improved by financial intermediation's external production of information concerning uncertain technology shocks. These shocks consist of two components, an aggregate component common to all agents in the economy and a private or idiosyncratic component. At the start of each period, intermediaries are able to learn the true size of the aggregate technology shock by funding or experimenting with a small number of projects. The resulting information concerning the true nature of the aggregate shock becomes public knowledge when intermediaries begin to fund projects.

Exploring a different channel, Bencivenga and Smith (1991, 1998) posit that financial intermediaries provide liquidity (insurance) to individual agents who are faced with a stochastic preferences shock over consumption in either the first or second period of an overlapping generations model. Financial intermediation increases the flow of savings into illiquid, yet high-return capital. Bencivenga, Smith, and Starr (1995) show that equity markets provide similar liquidity to agents, increasing investment in capital goods. Greenwood and Smith (1997) employ a similar environment, in part, to explore the impact of fixed set-up costs associated with the emergence of financial markets or networks. This approach provides insight into the shallow finance of developing countries, which is due to high borrower transaction costs associated with long distances to banking centers and poor transportation and communications systems.

Missing from these analyses is consideration of change, in the sense of Schumpeterian creative destruction, in institutional arrangements associated with the financial sector. This change results from profit-seeking behavior of agents. This dynamic perspective represents a more complete specification of Gurley and Shaw's (1955) observations concerning the importance of the subsequent development of a financial system. The model that emerges from Schumpeterian-Northian theory provides a more consistent explanation of financial sector progress and offers a theoretically improved means to investigate the interrelations between more productive financial services bundles, technological progress, and economic growth.

Davis and North (1971) show that the existence of uncertainty and private information are sufficient to create profitable opportunities for entrepreneurs to undertake costly institutional R&D. Arbitrage between industrial and financial institutional innovation will ensure that the expected returns on either form of R&D will be equal in the steady state. The entrepreneurial skills necessary to create a blueprint for an industrial or financial intermediate good are identical. Each vertical innovation is assumed to be drastic, i.e., the holder of a new intermediate goods or financial services blueprint produces such a qualitatively improved product that she is able to drive the incumbent out of the sector through the threat of Bertrand price competition and will earn monopoly profits until she, in turn, is replaced.

The financial service bundle is an intermediate good in R&D processes and incorporates all the various activities associated with funding uncertain R&D projects, given the existence of financial market frictions and controlling for repressive policies. The more recently the incumbent financial monopolist has innovated a new institutional arrangement, the higher is this associated productivity of the financial services bundle. Further, it is assumed that employment of this financial services bundle completely resolves all market frictions associated with asymmetries arising from private information.

CHAPTER 3

A MODEL OF ENDOGENOUS INNOVATION

Environment

Each country in the world consists of infinitely-lived agents who derive utility from a single consumption good and each are endowed with one unit of labor which is in-elastically supplied in a competitive labor market. Countries have an identical proportion of the population who are endowed with entrepreneurial skills. Finally, individuals are endowed with differing amounts of wealth that may be held in the form of physical capital or as financial claims. The implications of this environment are that skill-endowed agents will seek funding to undertake R&D expenditures to avoid the requirement of a double coincidence of endowments, i.e., entrepreneurial skill and wealth.

The entrepreneur has the ability to create and develop a new commercially feasible idea that may result in either a blueprint for a drastically superior product or process in one of the existing intermediate goods sub-sectors. Each such intermediate sub-sector or intermediate manufacturer is identified by the subscript *i*, where $i \in [0, N_t]$ and N_t represents the total number of industrial sub-sectors or product lines at time *t*. Alternatively, resources may be spent on institutional R&D with the hope of producing a blueprint for a new financial arrangement. There exist J_t different providers of the financial services bundle, each identified by the subscript *j*, where $j \in [0, J_t]$. In order to focus on the role of innovation in the process of growth and convergence, the model abstracts completely from trade in goods, services, or factors across national borders.

<u>Overview of an Economy with a Financial Sector</u>

Production of the aggregate flow of the single final good in a country, Y_{mt}, is represented by a standard neoclassic production function in which final goods producers employ labor and a spectrum of intermediate goods, x_{mit}. See Figure 3.1 below for an overview of the flow of resources in a Schumpeter-Aghion-Howitt (SAH) economy with private information. A Cobb-Douglas production function representation is presented in equation (1) below for tractability. The final goods market in a single country is assumed to be perfectly competitive.

$$(1) \quad Y_{mt} = C_{mt} + I_{mt} + R^{T}_{mt} = \int^{Nm}{}_{t} A_{mit} x_{mit}{}^{\alpha} di (L_{mt}/N_{mt})^{1-\alpha}, \text{ where } 0 < \alpha < 1.$$

The subscript *m* represents each individual country, m = (1, 2, …, M), where M is the total number of countries in the world. The single consumption good in the economy is C_{mt}. Investment or, equivalently, the amount of the final good that flows into the intermediate sector as capital, is represented by I_{mt}. The gross amount of the final good that flows into total R&D activities is R^T_{mt}, where $R^T_{mt} = R_{mt} + R^F_{mt}$.[25]

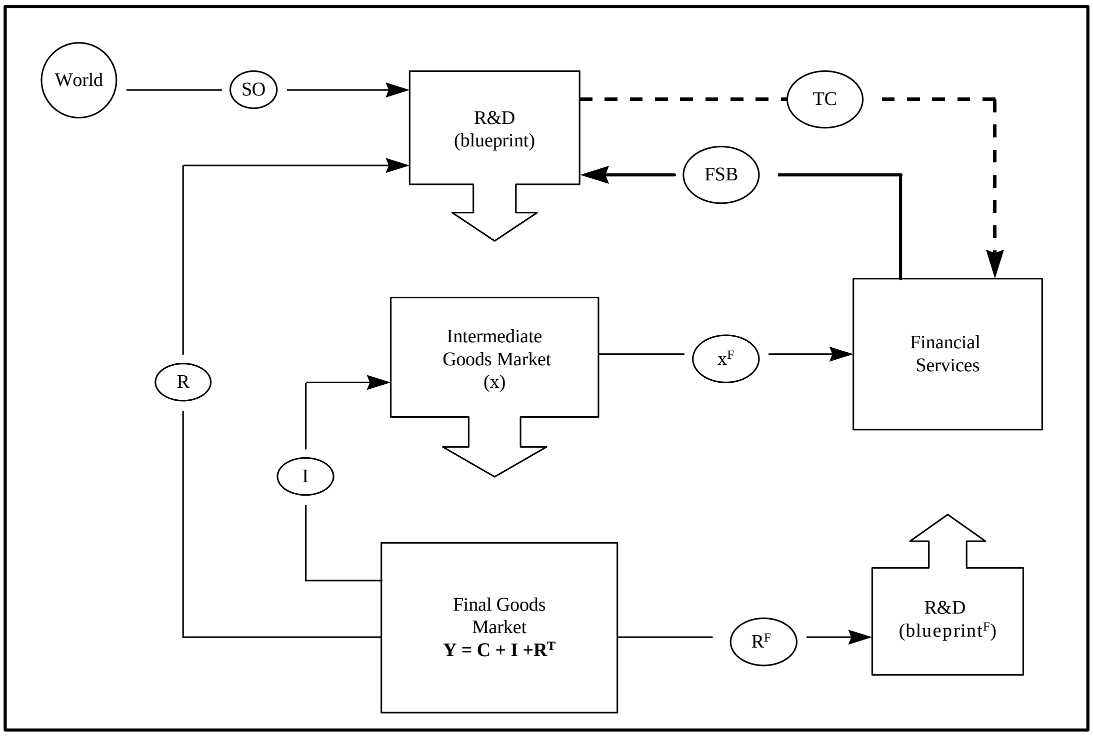

Figure 3.1 Schumpeter-Aghion-Howitt Economy with Private Information

The flow of final goods to entrepreneurs attempting to create a new blueprint for the manufacturing and financial sectors is R_{mt} and R^F_{mt}, respectively, where the F superscript represents flows associated with the financial sector. The level of the

[25] The optimal amount of resources that flow into either industrial or financial innovation is

population or number of workers is designated by $L^T_{mt} = L_{mt} + L^F_{mt}$. The growth rate of the population is exogenous for the purposes of this model. The ratios L_{mt}/N_{mt} and L^F_{mt}/J_{mt} represent the number of workers per final goods producer and financial services provider. These ratios are assumed to have already converged to the following constants, ℓ_m and ℓ^F_m, respectively.[26] This feature of the model avoids the counter-factual supply-side scale effect of the early innovation-lead growth models, as noted by Jones (1995).

Further, it means that, in any country, depending on its population growth rate, in addition to innovative activity some members of a society will engage in a form of imitation or copying which leads to a new product line, *i* at time *t*. However, domestic imitation neither increases the world's stock of technical knowledge nor the country's relative productivity parameter.[27]

Returning to equation (1), the productivity parameter associated with x_{mit}, the i^{th} intermediate goods sector in an economy, is represented by A_{mit}. When an innovation of a new intermediate good occurs in a specific industrial sub-sector, its productivity parameter jumps to the world leading-edge parameter: $A_t^{max} = \max\{A_{mt}(i) | i \in [0, N_t]$

---

determined by an arbitrage condition between the two sectors.

[26] See Aghion and Howitt (1998) and Howitt (2000) for further discussion of the propensity of individuals to imitate innovations and the growth of new industrial sectors that results from this process.

[27] In this model, horizontal innovations in themselves do not matter, which is, of course, an assumption that runs counter to Grossman and Helpman (1991). However, once in existence, the new sector will draw the interest of entrepreneurs and any new blueprint for this sector will impact the leading edge technology parameter.

and m = (1, 2, …, M)}; *m* is the country subscript and *i* denotes the respective country's industrial sub-sectors. The aggregate or average productivity parameter within a country at time *t* is represented by $A_{mt} = \int^{Nm} A_{mit}di$. The sector-specific innovation in a country increases, albeit marginally, the stock of world knowledge A_t^{max}.

One of the fundamental features of innovation is that as technological progress occurs, the next breakthrough idea requires an increase in the flow of inputs into R&D. To control for increases in complexity, it is necessary to discount the flow of resources into R&D by the leading-edge productivity parameter. The productivity-adjusted flow of the final good into R&D per industrial sector is as follows.

(2) $n_{mt} = R_{mt}/(A_t^{max}N_{mt})$.

One interpretation of this discount has been described as the "fishing out" effect in the literature on innovation; the first ideas to come to the market are those that require the least effort (cost). Subsequent ideas thus require increasingly more inputs to achieve. This feature reflects the existence of a braking mechanism on innovation-led growth. Without such a natural device, the world economy would have experienced explosive growth since the mid-to-late 18th century.

Entrepreneurs may enter freely into either of the R&D sectors (industrial or financial), based on each sector's expected returns to innovation. In the steady state, arbitrage will ensure that the two expected returns are equal. Given the existence of financial market frictions, some portion of the original flow of resources into R&D must now be used to secure a financial services bundle (FSB), which overcomes the market impediments associated with information asymmetries in funding R&D in period *t*.[28] See Figure 3.2 for the flow of resources into and out of the market for industrial R&D. The net flow of productivity-adjusted resources is represent by equation (3).

$$(3) \quad n_{mt} - \tau_{mt}q_{mt} = q_{mt},$$

where n_{mt} is the productivity-adjusted flow of resources, as defined above. A fee of $\tau_{mt}q_{mt}$, representing the total transaction costs to the industrial entrepreneur, is paid to the financial sector. The per unit transaction cost, τ_{mt} may also be viewed as the wedge between external funding and internal funding costs, an interpretation that is consistent with the current literature on financial innovation. The remainder of resources, q_{mt}, the net productivity-adjusted flow of the final goods into R&D, can only then be employed in the creation of blueprints. As shown in equation (4), the arrival of the next breakthrough industrial blueprint follows a Poisson rate of ϕ_{mt}.

$$(4) \quad \phi_{mt} = \lambda q_{mt},$$

[28] Financial innovation results in a new institutional arrangement, which is accompanied by new secondary action groups (organizations) and new instruments. The financial services bundle represents

where λ represents the physical productivity of resources employed in R&D. It is assumed to be time and geographically invariant.[29]

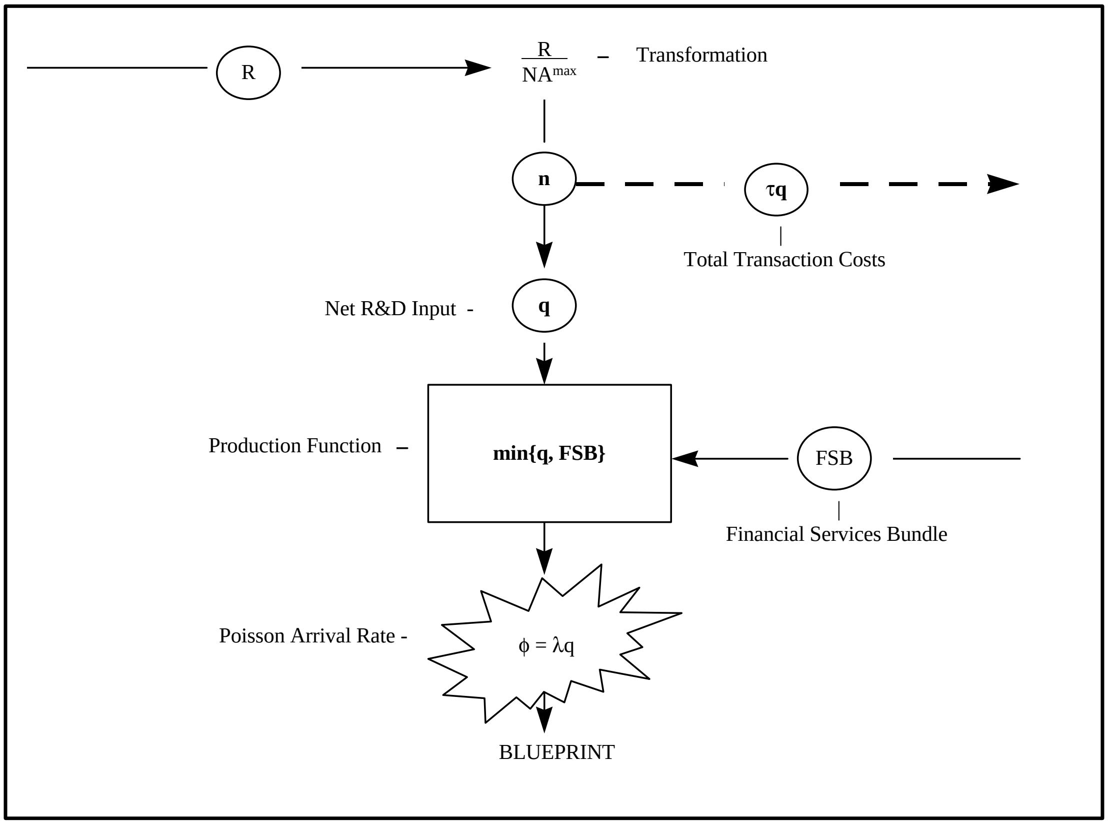

Figure 3.2 Inside the Black Box of Industrial Innovation

---

the final output of a new financial arrangement.

Role of Finance in Industrial R&D

Returning to financial development, the aggregate ability of the financial sector to overcome market impediments associated with asymmetric information is defined as financial sector development, (FD_{mt}). As financial sector development occurs, the proportional transaction cost, τ_{mt}, falls or better financial services effectively free up additional real resources for the creation of a new idea or blueprint. The following identity formally links the level of financial development with financial transaction costs.

(5) $FD_{mt} \equiv (1 + \tau_{mt})^{-1}$.

Financial market development is defined over $FD_{mt} \in [0,1]$. A value of 1 corresponds to the standard neoclassical assumption concerning the absence of market frictions and associated transaction costs in funding R&D. At the other extreme, at a low level of financial development (autarky), the costs of overcoming impediments to financial trade become quite large (infinite), the case of the primitive economies of Gurley-Shaw-McKinnon.

---

[29] The assumption of a "featureless plane" is common but not realistic. For example, Easterly and Levine (2000) point out that innovative activities tend to agglomerate in specific regions.

Making use of the relationship expressed in equation (3) and substituting the above equality into equation (4), the arrival rate of a useful idea for an intermediate good is given by the following equation.

(6) $\phi_{mt} = \lambda F D_{mt} n_{mt}$

Assuming for a moment that the world consisted of a single country, the differential equation governing the change of the leading-edge industrial productivity parameter is represented by $\mathring{A}_t^{max} = A_t^{max} \sigma \lambda F D_t n_t$, where σ represents the spillover of ideas across an economy's industrial sub-sectors. The physical productivity of R&D inputs, λ, is assumed to be constant across all sectors and over time. In a single-country world, the growth rate of per capital real income, g_t, is defined as follows, $g_t = \mathring{A}_t^{max}/A_t^{max}$. We will see that the world's endogenous growth rate below is similar.

Since the only uncertainty in this model is associated with the arrival of an innovation of a new intermediate good or financial blueprint, it is assumed that there exist no impediments to trade in the capital market. In the steady state, the one plus rate of interest is equal to the marginal revenue product of capital in the aggregate production function, which takes the form, Y = F(K, AL). Employing the Cobb-Douglas production function, the market clearing interest rate is represented by the equality, $r_{mt} = \alpha^2 k_{mt}^{\alpha-1} - \delta_t$, where k_{mt} is the amount of capital per effective worker and δ_t is the depreciation rate of capital. The following sub-section derives an expression of profits for the industrial sector.

Intermediate Goods Production

In a country, each successful industrial entrepreneur armed with a blueprint enters into the production of an intermediate good. With a drastic vertical innovation, the new manufacturer replaces the existing or incumbent firm in a particular manufacturing sub-sector. Thus, each x^T_{mit} is produced by a single agent or firm that is able to charge the full monopoly price. Since the market for final goods is perfectly competitive, the Schumpeterian monopolist sets a price of the intermediate good equal to the marginal revenue product of x_{mit} in the production of final goods, $p(x)_{mit} = \alpha A_{mit} x_{mit}^{\alpha-1} \ell_m^{1-\alpha}$.

Each intermediate good x_{it} is produced using only capital, K_{mit}, given the following production function, $x^T_{mit} = K_{mit}/A_{mit}$. Capital employed in intermediate production is divided by the sectoral productivity parameter. This is done to capture the observable increasing complexity of intermediate good production; greater amounts of capital are necessary to produce an equivalent amount of the intermediate good, x_{it}, with each new sectoral innovation. Finally, the capital market clearing condition can be shown to be $K_{mt} = \int^N A_{mit} x^T_{mit} di$.

Total revenue for the industrial monopolist is $TR_{mit} = \alpha A_{mit} x_{mit}^{\alpha} \ell_m^{1-\alpha}$ and total cost of production of the intermediate good is $TC_{mit} = \xi A_{mit} x^T_{mit}$, where $\xi_m = (r_{mt} + \delta)$. Examination of the above relationships reveals that for each intermediate manufacturer in the economy, both costs and revenues are proportional to the sector's productivity parameter. Thus, the optimal level of output for each firm across all sectors in a country is the same, $x_{mt} = x_{mit}$ for all i's. The profit function of the manufacturing monopolist in each sector is represented by the equation (7).

$$(7) \quad \pi_{mit} = \alpha A_{mit} x_{mit}^{\alpha} \ell_m^{1-\alpha} - \xi A_{mit} x_{mit}.$$

Solving the first-order condition for profit maximization and with proper substitution, yields the following function, which relates profits to capital intensity.

$$(8) \quad \pi_{mit} = A_{mit} \alpha(1-\alpha) k_{mit}^{\alpha} \ell = A_{mit} \pi(k_{mt}) \ell_m,$$

where $k_{mt} = K_{mt}/A_{mt}L_{mt}$. A new intermediate goods manufacturer is herself subject to replacement by the next sectoral industrial innovator. The expected value of a new industrial innovation is

$$(9) \quad V_m = A^{max}{}_t\int^{\infty} e^{-rs} \pi({}_m k_t) e^{-\int \phi du}\, ds, \text{ where } \phi_{mt} = \lambda FD_{mt} n_{mt}.$$

Equation (9) represents the discounted present value of all future profits from an innovation, multiplied by the probability of the arrival of the next replacing innovation. As in the neo-classic growth model, capital accumulation alone will eventually suffer from diminishing marginal returns. Similarly, an innovative society that does not accumulate capital will find diminishing returns to new ideas, as introduced above. Increased amounts of capital in a society will raise the profits of intermediate manufacturers and lower the interest rate used to discount all future cash flows generated by an innovation.

Industrial Innovation and Profits

The expected profits of the successful industrial entrepreneur can be derived by evoking a steady state arbitrage condition, equality between marginal cost of R&D and marginal benefits of industrial innovation. The marginal cost of an additional unit of the net R&D input is $(1 + \tau_{mt})A^{max}_t$, where A^{max}_t can be viewed from the finance literature as internal funds or the amount of the consumption good needed to raise the productivity-adjusted level of R&D by one unit. The second term represents the entrepreneur's cost of financing this next unit of R&D. The marginal benefit is equal to the expected profits of this additional unit or λV_{mt}. Here λ represents the flow probability of achieving the next innovation and V_{mt} represents the value of the next innovation.

(10) $(1 + \tau_{mt})A^{max}_t = \lambda V_{mt}$.

Solving equation (9) and rearranging equation (10) provides the following equality:

(11) $$V_{mt} = \frac{A^{max}_t \lambda \pi(k_{mt})\ell_m}{r_{mt} + \phi_{mt}}.$$

The industrial R&D sector may be subject to targeted government subsidies, taxes, or other market distortions. Let ψ_{mt} represent such factors, $0 < |\psi_{mt}| < 1$. Substituting equation (11) into equation (10) produces the finance-augmented industrial research arbitrage equation.

$$(12) \qquad (1 - \psi_{mt}) = \frac{\lambda FD_{mt}\pi(k_{mt})\ell_m}{r_{mt} + \lambda FD_{mt}n_{mt}}$$

Expected profit flows are discounted by the net rate of interest and by the Schumpeterian rate of creative destruction, $\lambda FD_{mt}n_{mt}$, the productivity of R&D inputs times the flow of resources into industrial R&D. The steady state level of productivity-adjusted flow R&D per sector is shown in equation (13). The country-specific subscript is suppressed for notational simplicity and note that *n** represents the steady state level of productivity-adjusted R&D flow per sector.

$$(13) \qquad n^* = \frac{\pi(k)\ell}{(1-\psi)} - \frac{r(k)}{\lambda FD}.$$

It can be shown through proper substitution that the following solution for the steady state value of the unadjusted flows into industrial R&D is equivalent to the above equation.

$$(14) \qquad n^* = \frac{a^{-1}\alpha(1-\alpha)(Y/L)\,\ell}{(1 - \psi)A^{max}} - \frac{\alpha^2(Y/K) + \delta,}{\lambda FD}$$

where the country *m*'s relative productivity parameter is defined as $a_m = A_m/A^{max}$.

Proposition 1 *The productivity-adjusted flow of resources into industrial R&D, per sector, is increasing in the level of financial development (FD), per capita income (Y/L), capital intensity (K/Y) , and in the level of sector-specific policies (ψ). Conversely, the productivity-adjusted R&D is decreasing in the relative productivity parameter (a) and in the capital depreciation rate(δ) .*

Productivity-adjusted resource flows into R&D are decreasing in the ratio of a country's average productivity parameter to the leading-edge parameter, a_t. This is a key component in the story of club convergence and will be further developed below. Also of interest is the implication that improved financial depth (FD) increases the steady state flow of real resources into R&D, even as increased values of the relative productivity parameter slow growth. While unresolved in this dissertation, the tension between these two factors would further slow individual country convergence to its own steady state. According to Howitt (2000), one of the counterfactual implications of the augmented neoclassical growth model, as estimated in Mankiw, Romer, and Weil (1992), is that it implies convergence rates, e.g., countries converge too quickly. The following sub-section derives a similar equation that determines the steady state level of financial sector development.

Endogenous Financial Development

Financial sector development, as defined by North and Davis (1971), is a Schumpeterian process in which entrepreneurs employ real resources to develop a blueprint for a superior financial arrangement and thus a “better” (cheaper) financial instrument or services bundle. In the context of this model, financial innovations lower the transaction costs (τ_t) of funding entrepreneurs, leading to higher levels of R&D. This has important implications for ultimate convergence of the Aghion-Howitt model to a steady state equilibrium.

As introduced at the beginning of this chapter, there are J_t firms in the financial services sector. As in the manufacturing sector for intermediate goods, each new financial blueprint allows the financial entrepreneur to replace an incumbent firm in a specific financial market sector. The existence of monopoly profits in this sector provides incentives to engage in costly institutional R&D. In the steady state, arbitrage will ensure that expected profits from either form of innovation are equal. Suppressing the country notation, *m*, the profit equation of an individual firm is as follows:

$$(15) \quad \pi_{jt} = P_t^F f_{jt} - c_{jt} h(f_{jt}) - \Gamma_j(c_{jt}, \psi^F),$$

where P_t^F is the market-determined price of the financial services bundle, f_{jt}. The homogenous services bundle overcomes impediments to finance associated with the uncertain and private arrival of the next industrial innovation or blueprint. The per unit cost of the financial bundle is c_{jt}. The inverse production function for the financial services bundle is represented by $h(f_{jt})$.[30]

The last term in equation (15), $\Gamma_j(c_{jt},\psi^F)$, is the cost function associated with financial innovation, which is required to enter a financial market sector. The function, Γ, is decreasing in both c_{jt} and in ψ^F. The latter variable represents the impact of financial sector-specific governmental policy associated with financial repression, as defined by Shaw (1973) and McKinnon (1973). The implication of this functional definition is that potential monopoly profits or the returns to financial innovation are highest when monitoring costs are highest or when repression is most severe. This is consistent with Gurely and Shaw (1955) and much of the historical record in the U.S.

Maximizing equation (15) with respect to f_j yields the following first-order condition (FOC) for an optimum.

$$(16) \quad P_t^F = c_j h'(f_j)$$

[30] The underlying direct production function follows the standard neo-classical assumptions.

In equilibrium, the supply of financial services is equal to the demand from industrial entrepreneurs. Given the assumed fixed-proportions production function employed in the industrial R&D sector, the demand for the financial services bundle is perfectly inelastic.

(17) $R_t = F_t = e^{\int \ln(f) dj}$,

where the terms of integration are over [0, 1], each financial firm sorted on the unit line by the relative productivity of its institutional arrangement in overcoming private information in an uncertain world. The aggregate supply of financial services is F_t.

Employing the envelope theorem and maximizing the firm's profit function, now with respect to the per unit (monitoring) costs, c_j, yields the following equations. For notational convenience, the exogenous variable, ψ^F, is suppressed below.

(18) $\pi'(c_j) = - h'(f_j) - \Gamma_c = 0.$

(19) $h'(f) = -\Gamma_c$

At the optimum, the marginal benefit of a cost-reducing innovation is just offset by the costs associated with the current production level of f, given the common inverse production function, h(f), and the exogenous aggregate demand for financial services. I substitute the equality in equation (19) into equation (16) to form equation (20).

(20)) $P_t^F = -c_j \Gamma_c$, where $\Gamma_c < 0$, by definition.

Aggregating over all J financial firms, $C = e^{\int \ln(c)dj}$ given that the terms of integration are [0,1]. Setting the price of finance equal to the per unit transaction cost associated with R&D flows and substituting R_t for F_t in equation (20) leads to the following functional representation.

(21) $\tau_t = P_t^F = p(C_t , R_t, \psi^F)$,

From the discussion above we know that τ is decreasing in financial innovation, as represented by the Γ function. Changes to this function are motivated by the potential to earn monopoly profits. In this equation, τ_t is decreasing in R_t. This is based on assumed increasing returns to scale in the provision of the financial services bundle. Financial transaction costs are assumed to be increasing in financial repression, ψ^F, as discussed in Chapter 2.

Financial development is defined as the inverse of one plus τ. Substituting this identity in equation (21) and taking the natural logarithm of both sides yields the following equation (22). I have normalized the flow of resources into R&D by GDP to obtain R&D intensity, which is one of the critical variable under consideration here.

$$(22) \quad \ln(FD_t) = \ln(C_t) + \ln(R/Y_t) + \ln(Y/L_t) + g_{Lt} + \ln(\psi^F)$$

Proposition 2 *The level of financial development (FD) is increasing in the flow of R&D intensity (RD/Y), per capita income (Y/L), and the population growth rate (*g_L*). Financial sector development is decreasing in the level of aggregate unadjusted monitoring costs (C), and the level of sector-specific policy interventions (*ψ^F*).*

In order to transform equation (22) into a regression equation, the following definition is employed.

$$(23) \quad \ln(C_t) = \ln(C_0) + g_c t.$$

The variable $g_c t$ is the growth rate of monitoring costs, which is assumed to be constant. The initial level of financial production or monitoring costs, C_0, represents country specific characteristics, e.g., geographical features or societal norms, which are subject to external shocks.

(24) $\ln(C_0) = \underline{c} + \upsilon$, where $\underline{c}$ is a constant.

As introduced above, financial innovation offers mechanisms to ameliorate the impact of such shocks. The following section will derive an endogenous growth version of the Solow-Swan equation and will follow directly from Aghion and Howitt (1998a, Chapter 12) and Howitt (2000).

The Schumpeter-Solow Equation

Following Howitt (2000), the neoclassic Solow model is represented by the following differential equation:

$$(25) \quad [dk_{mt}/dt] = s_m k^{\alpha}_{mt} - [\delta + g_{Lmt} + g_t] k_{mt}.$$

The savings rate is represented by s_m. In the neoclassic Solow representation, the world growth rate is assumed to be exogenous. In the Schumpeterian framework, the endogenous world growth rate is defined by equation (26).

$$(26) \quad g^W_t = \mathring{A}^{max}/A^{max} = \Sigma^M \sigma\lambda FD_m n_m.$$

In order to fully derive the Schumpeter-Solow equation, a slight diversion into convergence is necessary.

According to Mankiw, Romer, and Weil, (1992), the Solow growth model supports conditional convergence or convergence of all countries to the same steady state level, conditional on a country's savings rate and population growth rate. Conversely, the Schumpeterian-Solow model predicts that countries that undertake R&D activities will, in fact, converge to the same steady state growth rate. This feature is consistent with the stylized facts of club convergence. However, each country will have a different productivity level in the steady state, a fact detailed in Hall and Jones (1996), that the standard neoclassical model fails to explain. The ability to join the club is dependent on the incentives to innovate and to accumulate capital that stem from a society's institutional environment and subsequent development of its institutional arrangements. In the model of this dissertation, institutional change is captured by financial sector change.

The main mechanism for convergence of steady state growth rates comes from technology transfers in the form of knowledge spillovers. Local entrepreneurs are able to access the world stock of knowledge to produce the next innovation in a sector in their home country. Convergence, from transitional dynamics, comes about because growth of the relative productivity parameter will slow as a country moves closer to its steady state output level from below. A country's productivity parameter is determined as follows.

$$(27)\ \mathring{A}_{mt} = \lambda FD_{mt} n_{mt} (A_t^{max} - A_{mt}).$$

As introduced earlier, a country's relative productivity is defined as $a_{mt} \equiv A_{mt}/A_t^{max}$. The distribution of this variable will vary by country; a technologically leading country will have the majority of its sectors close to the leading edge productivity parameter or otherwise. Countries with high levels of R&D intensity, supported by a well developed financial market, will have more innovation and thus a higher proportion of their intermediate sectors with relatively recent innovations. In this case, the country's relative productivity will be closer to one.

Using the definition of the world growth rate, the differential equation (28) represents the growth of the relative productivity parameter in each country, *m*.

(28) $\mathring{a}_m = \lambda FD_{mt}n_{mt}(1- a_{mt}) - g^W_t a_{mt}$.

Thus, as a country increases the flow of resources into R&D, the gap $(1-a_{mt})$ narrows, slowing productivity gains, and eventually the innovating country's growth rate will equal the global growth rate g^W_t. Invoking the steady state condition and solving equation (28) for this growth rate, produces the following representation:

(29) $g^W_t = \lambda FD_m n_{mt}(a_{mt}^{-1} - 1)$

Again, assuming a steady state and substituting equation (29) into equation (26) yields the following representation.

$$(30) \quad k_m^* = \{s_m[\delta + g_{Lm} + \lambda FD_{mt} n_{mt}(a_{mt}^{-1} - 1)]^{-1}\}^{(1/1-\alpha)}$$

Completing the endogenous regression model requires substitution for the relative productivity parameter. Solving equation (21) for the steady state relative productivity parameter and taking a log-linear approximation of the resulting equation produces the following relationship:

$$(31) \ \ln[a_m] \cong \text{constant} + \kappa\{\ln(RD/Y)_m + \ln(Y/L)_m + \ln(FD/Y)_m - g_{Lm} - \ln[A^{max}]\}$$

Finally, substituting equation (31) into equation (30) and taking the log of the aggregate production function results in a Schumpeter-Solow regression equation that controls for both R&D levels and financial depth in explaining cross-country differences in productivity and levels of per capita income.[31]

$$(32) \quad \ln[Y/L] = b_0 + b_1[\ln(s_k) - \ln(\delta + g_L + g)] + b_2[\ln(s_h) - \ln(\delta + g_L + g)]$$
$$+ b_3\ln(RD/Y) + b_4\ln(FD) + b_5\ln(g_L) + g_t.$$

In the most recent cross-country studies, savings have been split into physical capital (s_k) and human capital (s_h) accumulation. The variable A^{max}, the world's leading edge productivity parameter does not vary across countries. The R&D productivity

[31] Since all countries share a common leading-edge technology parameter, A^{max} contains no explanatory power in cross-country investigations of income differences. Also note that

parameter, λ_m, and the number of workers per sector, ℓ_m, are constants and thus appear in the constant term in subsequent regressions.

The following chapter will deal with the empirical problems associated with estimating the equation (32), due to the existence of endogenous variables, R&D and financial development, as right-hand-side variables.

$b_1 = b_2 = (1/1-\kappa)(\alpha/1-\alpha-\beta)$ and $b_3 = b_4 = (\kappa/1-\kappa)$, where κ is associated with a country's expenditure on R&D intensity.

CHAPTER 4

THE EMPIRICAL MODEL

In order to deal with the presence, in equation (32), of endogenous regressors, R&D intensity and financial development, a system of three equations is developed in this chapter. First, the primary question of interest, the augmented Schumpeter-Solow can be written as a regression equation, as follows. Note that the country subscript *m* has been suppressed here. [32]

$$(R_1) \quad \ln[Y/L] = \gamma_{21}\ln[RD/Y] + \gamma_{31}\ln[FD] + \beta_{01} + \beta_{11}\ln[S_k] + \beta_{21}\ln[S_h] + \beta_{31}g_L + \beta_{71}T + \varepsilon_1.$$

The variable *T* stands for the time trend that must be included in the panel data regressions. The coefficient on this variable is associated with the growth rate of knowledge across all countries in the sample. Equation (R_1) represents economies in the steady state. In subsequent regressions, the initial level of per capita income is used to control for transitional dynamics of the post-war period for OECD countries.

[32] In equation (R_1), $S_k = s_k - (\delta + g_L + g_t)$ and $S_h = s_h - (\delta + g_L + g_t)$, respectively.

The presence of the other endogenous variables, R&D and financial depth, however, would lead to biased estimators if an ordinary least squares (OLS) regression were performed. To address this problem, two additional equations are added to the primary equation to form a system of equations, which can be estimated using a two- and three-stage least squares procedures. Lagged values are used for investment in physical and human capital, to avoid additional simultaneity bias.

There remains an additional empirical issue to overcome in order to obtain consistent estimates. As in Davis and North (1971), the formal model assumes that the institutional environment or "rules of the game" is exogenous. Thus, any aggregate shocks to an economy's institutional superstructure, which effects the three endogenous variables of interest, will be unobserved or will act as a latent variable within the model. Empirically, the respective error terms of each of the three simultaneous empirical equations will be contemporaneously correlated. According to Judge et al. (1988), "when the objective is joint estimation of the parameters for all structural equations in the system, the seemingly unrelated regression techniques permits us to use the information contained in the covariance among the structural equation errors to construct a three-stage least squares estimator." (p 637) The error terms are assumed to follow the standard Gauss-Markov assumptions.

The second equation follows directly from the formal model derived above. Solving for R&D intensity and performing a log-linearization of equation (14), the finance-augmented research arbitrage equation, yield the following result.

$$(R_2) \quad \ln[RD/Y] = \gamma_{12}\ln[Y/L] + \gamma_{32}\ln[FD] + \beta_{02} + \beta_{42}\ln[K/Y] + \beta_{52}\ln[\psi] + \varepsilon_2$$

Lagged values for the capital intensity variable are used to ensure consistent results. This is also the case for the proxy for R&D specific market subsidies or other distortions. The final equation, which treats financial development as the dependent variable, is as follows:

$$(R_3) \quad \ln[FD] = \gamma_{13}\ln[Y/L] + \gamma_{23}\ln[RD/Y] + \beta_{03} + \beta_{63}\ln[\psi^F] + \beta_{33}g_L + \varepsilon_3$$

In addition to per capita income and the R&D intensity variable, sector-specific distortions are included. As will be discussed below, two measures are used to capture the impact of financial repression, as defined by Shaw (1973) and McKinnon (1973). These proxies are inflation, lagged one period and an indicator of banking system distortions, which is captured by size of financial markets. The first proxy is based on a long tradition in the development finance literature, most recently articulated in Boyd, Levine, and Smith (2001). These authors contend that inflation serves as a meaningful measure of government-induced financial market distortions. Additionally, the authors also argue that inflation will exacerbate the distorting effect of credit rationing. Given the plausible assumption of private information over the Poisson arrival of innovations, it is not necessary to consider an additional informational asymmetries in this model specification.

The second measure of financial market-specific distortions, market size, is related to repressive policies, such as import substitution strategies, creation of targeted lending institutions, low interest rate ceilings, high reserve requirements, and controlled leading to government entities, as outlined in Shaw (1973). The size variable is the result of the addition of two financial stocks, the level of outstanding credit to the private sector (PSC) and the capitalization of formal equity markets (CAP).

The primary test of the model uses cross-sectional data created by averaging the data over the full 25-year period. The processes involved in the achievement of sustained growth occur over much longer periods; however, due to data limitations most empirical growth studies are restricted to the post-war period. As a secondary test, the data are averaged over consecutive five-year periods, and TSLS panel regressions are performed.

The two testable hypotheses of the formal model are that R&D explains the differences in per capita income levels and that financial development influences the flow of resources into R&D, i.e., I expect a positive value for the coefficients γ_{12} and γ_{23}. Based on logic employed in Benhabib and Spiegel (1999), the coefficient on financial development, γ_{13}, should be statistically insignificant. In explaining differences in per capita income levels, finance, in this model specification, should not have a direct impact on per capita income. The following chapter discusses the data and its sources.

CHAPTER 5

DATA DESCRIPTION

Data for R&D and National Income and Product Accounts

This dissertation employs a set of core data that have been previously collected and widely used in evaluating various growth models. Data on the National Income and Product Accounts variables originate from Summers and Heston (1992), PTW5.6, augmented by the World Bank's "Global Development Finance & World Development Indicators," as described by Easterly and Levine (2000). The variables from these sources are, per capita income (Y/L), the rate of capital investment (S_k), inflation (inf), and the initial level of pre capita income $(Y/L)_0$.

This traditional data set is not without shortcomings. Especially problematic are sources for data on the series measuring human capital accumulation or stocks. The most widely used source for such data is Barro and Lee (1996). As is common in recent growth studies, this dissertation proxies the stock of human capital (HC) by the average years of education in the working population, people who are 15 years or older. The series for capital intensity (K/Y), for OECD countries, is taken from the recent PTW5.6, which uses disaggregated measures of capital, with varying rates of depreciation to calculate the stock. This represents an improvement upon the capital stocks series created using a common depreciation rate and the perpetual inventory method.

The formal model controls explicitly for government subsidies, taxes, or other R&D sector-specific distortions (ψ). From Northian theory, any policy-related intervention of these types would likely be endogenous. The net effect of all these various policy factors is captured using the patent right index (PSI) developed by Ginarte and Park (1997). The components of the index include the length of patents and other statutes or regulations that govern the ownership and enforcement of rights over intangible assets. A one period lag of this variable is used in the regression analysis.

Financial Sector Data

Financial sector measures are from the World Bank's "Financial Structure Data Set," as described by Beck, Demirguc-Kunt, and Levine (2000). Financial sector development (FD) measures how well a society is able to overcome market frictions associated with information asymmetries inherent in funding uncertain expenditures on R&D. The more developed the financial market, the lower will be the transaction costs (τ) of the financial contract and the more productive the resources employed in the creation of new ideas will be. In order to capture the level of development of this sector, the empirical study uses measures associated with the efficiency of the banking system in turning deposits (liquid liabilities) into loans to the private sector (bank credit). Operationally, the level of bank credit, private sector credit less other financial intermediary credit, (BC) is divided by the level of liquid liabilities, (LL). High values of this ratio (BCLL) indicate greater efficiency in the banking system's ability to fund borrowers, specifically the marginal borrower (the industrial entrepreneur). The provision of funding for new, highly productive projects is dependent on the reduction of financial sector transaction costs.

Although this measure of productive efficiency seems to most closely match the underlying theory, more traditional measures of financial development, such as the size of formal intermediation, private sector credit per GDP, and the size of the formal stock market, as measured by capitalization, normalized by GDP, are tested below. See Levine et al. (2000) for a more detailed discussion of these variables.

A third alternative proxy for financial development based, on Beck and Levine's (2000) interesting study of the impact of financial depth on new firm formation in industries, is also tested. Unfortunately, the authors' proposed measures of financial development blur the distinction between financial stocks and flows. Beck and Levine derive a new measure of financial development, financial market activity, by multiplying outstanding private sector credit by the value of equities traded in the year, a flow variable. It is unclear what this measure precisely captures, alone or in combination with other financial stock series. This proposed measure may be able to better capture characteristics associated with lowering monitoring costs associated with funding R&D, but it dimension seem to be internally inconsistent. Collection of several new series related to financial market development, beginning in the early 1990s, has been recently undertaken by the staff of the World Bank. See Beck et al. (2000) for a description of the new series of banking data.

As in the market for industrial blueprints, specific government policies (ψ^F) may disrupt the flow of resources into the creation of a new financial blueprint. Examples of policies in the U.S. include restrictions on branch banking or new entry, prohibition of specific financial activities, or subsidization of non-profitable competing intermediaries, e.g. failing savings and loans associations. In order to capture these financial sector-specific policies, measures related to the size of the formal financial sector, which combine the total amount of loans outstanding to the private sector and stock market capitalization.

In terms of developing countries, Shaw (1973) and McKinnon (1973) more generally speak of repressive financial regimes, as those associated with development strategies of import substitution. According to these authors, the level of financial repression should be reflected in the size of financial markets. Also see Gonzalez-Vega (1993) for an interesting discussion of the impact of repression on rural financial markets, arguably the most vulnerable financial market. In this tradition, inflation has also been employed as a measure of government repression. Most recently, Boyd et al. (2001) include an inflation indicator as a measure of repression in a study of financial development. The following table presents the descriptive statistics for the cross-sectional variables employed in the regression.[33]

Average Values (1971-1995)

Variable	Mean	Std Dev	Variance	CV*
ln(Y/L)	9.3092	0.2688	0.0723	0.0078
ln(RD/Y)	0.2726	0.6535	0.4271	1.5668
ln(FD)	0.2363	0.2961	0.0877	0.3711

Initial Values (1970)

Variable	Mean	Std Dev	Variance	CV*
$\ln(S_k)$	3.0909	0.1959	0.0384	0.0124
ln(HC)	1.9544	0.3289	0.1082	0.0554
ln(KY)	0.0402	0.3521	0.1239	3.0821
ln(PSI)	1.0961	0.1661	0.0276	0.0252
ln(inf)	1.4174	0.2751	0.0757	0.0534
ln(size)	-0.2907	0.3945	0.1556	0.5353
$\ln(YL)_0$	8.9317	0.3597	0.1294	0.0145

*Coefficient of Variation (absolute value)

Table 5.1 Descriptive Statistics for Cross-Country Data

The coefficient of variation is calculated by dividing the sample variance by its mean and is used to compare the underlying variation of different variables across countries.

[33] The data have been transformed using the natural log function and averaged over the 25 year period (1971-1995).

Aside from the capital intensity variable, R&D intensity has the largest variation in the sample, which is consistent with Hall and Jones' (1996) observation that productivity varies widely even in the OECD sample.

CHAPTER 6

FINDINGS AND CONCLUSION

The regression results support the Schumpeterian hypothesis that industrial innovation, as proxied by R&D intensity, plays an important role in understanding the achievement of modern growth. The findings also provide evidence that endogenous financial development that lowers transaction costs positively affects the level of R&D undertaken in a country. This result is consistent with North's hypothesis concerning the importance of institutional change in shaping economic growth.

As introduced above, Mankiw, Romer, and Weil's (1992) early test of the Solow model, using cross-country data averaged over the sample period, has been a focal point in the exogenous-endogenous growth debate. To place this dissertation's findings in the larger growth context, the Mankiw et al. regression is replicated here for the OECD sample averaged over the 1961-1985 period. Even though the empirical methodology is flawed, the results of adding first R&D intensity and then financial development to the base Mankiw out-of-steady state regression are instructive. To control for transitional dynamics associated with the post-war period, the series of regressions to follow include the initial value of per capita income.

Cross-Section Regression
Dependent Variable is $\ln(Y/L)_{1985}$

	MRW…		with R&D		and FD	
		S.E.		S.E.		S.E.
Constant	0.6222	0.9221	3.0251*	1.3064	3.7182*	1.4331
$\ln(S_k)$	0.3953*	0.1373	0.2537	0.1401	0.1782	0.1432
$\ln(S_h)$	0.2412	0.1288	0.1154	0.2218	0.2045	0.1273
ln(RD/Y)			0.1494*	0.0666	0.1269	0.0665
ln(FD)					0.1150	0.0880
$\ln(Y/L)_0$	0.5978*	0.0626	0.4330*	0.0930	0.4226*	0.0918
R^2	0.8742		0.8998		0.8604	
Implied α	0.2416		0.1537		0.1166	
Implied β	0.1474		0.1343		0.1338	
implied κ			0.2086		0.1802	
implied λ	0.0206		0.0335		0.0345	
OBS	22		22		21[34]	

* - significant at 5% level.
Data is averaged over sample period (1960-1985).

Table 6.1 OLS Estimation of Mankiw, Romer, Weil with R&D and Finance

Introduction into the augmented-Solow model of R&D and financial development follows directly from theory. The additional variables reduce the omitted variable bias present in previous growth studies. Ignoring other empirical problems, for a moment, and running a simple OLS regression, the coefficient on the R&D variable is positive in both extended regressions. The results, shown in Table 6.1, are supportive of the Schumpeterian hypothesis, despite the lack of statistical significance of most of the key variables under consideration. After transforming the coefficient values into the structural parameters of the Schumpeter-Solow equation, the parameter value associated with R&D intensity, κ, is above 0.18 in the final two regressions, which is larger than either of the parameters associated with physical and human capital accumulation.[35] The results of the Mankiw et al. regression point to convergence rates (to individual steady states) of about 2 percent, while the fully augmented regression predicts a rate of convergence of over 3 percent.

The structural parameters associated with physical capital and human capital decline with the introduction of R&D in the second regression test. This is consistent with Howitt's (2000) assertion that omitting R&D from the Solow regression equation will bias the coefficient on capital accumulation upwards.

The value of the financial variable in the primary Schumpeter-Solow equation should be insignificant after controlling for capital accumulation and R&D intensity, both theoretically and empirically, as shown in Table 6.1.

In the next subsection, a similar cross-sectional regression is performed on data

[34] Turkey is omitted from the sample due to insufficient financial data. Ireland is removed from the sample in the regressions to follow because of the lack of equity market information.

averaged over the 1970-1995 period. The new 25-year sample period is necessary to accommodate the use of improved measures for R&D and financial development. Additionally, Mankiw et al.'s savings rate for human capital is replaced by Barro and Lee's (1996) measures of average educational attainment, a more widely accepted measure.

The same uncorrected OLS regression employed in the first test is run using data for the new sample period to insure that the change in the sample does not unduly impact the findings. The results, which are note presented here, are roughly the same the as in Table 6.1. The coefficient on the R&D variable is positive and significant and implies a value of approximately 0.19 for κ.

In order to improve upon the earlier analyses that did not control for endogeneity of several regressors, two-and-three stage least squares methods are employed here. The results of the three-stage least squares (TSLS) regression are be presented in Table 6.2 because this method produces more efficient error terms, necessary for hypothesis testing. Lower coefficient values and higher standard errors from the simple two-stage least squares regression, when compared with TSLS results, demonstrate that there exists a contemporaneous correlation between the error terms of the system's equations.

---

[35] The coefficient on the natural log of R&D is equal to $\kappa/(1-\kappa)$, where κ is the parameter associated with R&D or the productivity level in the formal model.

In the first equation, the augmented Schumpeter-Solow equation, the initial values rather than period average values of both physical capital investment and the stock of human capital are employed to avoid potential identification problems of the Mankiw et al. (1992) regressions, as discussed by McGratten and Schultz (1998).

Three Stage Least Squares Cross-Sectional Regression
Without and With Endogenous Financial Development

Equation 1	**Dependent Variable is ln(Y/L)**			
		S.E.		**S.E.**
Constant	4.7969*	2.2792	4.3265*	1.4539
ln(RD/Y)	0.1586	0.1421	0.2166*	0.0999
ln(FD)			-0.2503	0.1378
$\ln(S_k)$	0.0433	0.0986	0.0971	0.0807
ln(HC)	0.0162	0.0622	-0.0552	0.0900
$\ln(Y/L)_0$	0.4826*	0.2393	0.5223*	0.1535
Implied κ	0.2347		0.3120	
Implied λ	0.0291		0.0260	
Equation 2	**Dependent Variable is ln(RD/Y)**			
		S.E.		S.E.
Constant	-15.4875*	3.5770	-15.2536*	2.6635
ln(Y/L)	1.6049*	0.4364	1.6842*	0.2973
ln(FD)			0.8762*	0.1895
ln(K/Y)	0.2671	0.2245	0.0015	0.0894
ln(PRI)	0.6879	0.5994	0.0494	0.2456
Equation 3	**Dependent Variable is ln(FD)**			
				S.E.
Constant			17.8574*	5.5572
ln(Y/L)			-1.9754*	0.5981
ln(RD)			1.1609*	0.2682
ln(inf)			-0.0193	0.0999
ln(size)			-0.0214	0.0782
System R^2	0.7742		0.7643	

* - significant at the 5% level.
Data is averaged over sample period (1971-1995).

Table 6.2 Estimation of a System of Equations Using Cross-Sectional Data

The first regression is run without controlling for endogenous change in the institutional arrangements associated with financial markets, in order to measure the impact of the potential bias of failing to control for Northian institutional change.

As shown in Table 6.2, the key R&D variable enters the first equation with a positive sign. The implied value of the structural parameter, κ, increases to about 0.23. In the second regression, to which endogenous financial development is added, the coefficient on R&D intensity is positive and significant in the primary equation. The elasticity of per capita income with respect to R&D intensity increases to 0.31. The coefficient on the financial variable is statistically insignificant in the primary equation. These results are consistent with *ex ante* expectations. In the second equation, in which R&D intensity is the dependent variable, the coefficient associated with financial development is positive and both economically and statistically significant.

The next exercise retains the TSLS regression technique but attempts to exploit the time series dimension of the data, which are averaged over consecutive five-year periods from 1971 to 1995. Five year-averaged data have long been employed to attempt to minimize the impact of cyclical fluctuations in cross-country growth studies.

The employment of the TSLS regression using panel data requires the assumption that the OECD countries are sufficiently homogenous, i.e., that they have a common intercept term. Mankiw (1995) supports the interpretation that these advanced countries are sufficiently similar that any omitted variable bias from not controlling for country specific differences should be minimum. The panel regressions results are presented in Table 6.3.

Three Stage Least Squares Panel Regression
Common Intercept

Equation 1	**The Dependent Variable is ln(Y/L)**	
		S.E.
ln(RD/Y)	0.0913*	0.0443
ln(FD)	0.1010	0.1088
Constant	-92.2632	21.521
$\ln(S_k)$	0.0975*	0.0391
ln(HC)	0.0406	0.0851
ln(Time)	0.0490*	0.0107
$\ln(Y/L)_0$	0.5426*	0.0799
Implied κ	0.1664	
Implied λ	0.0245	
Equation 2	**The Dependent Variable is ln(RD/Y)**	
		S.E.
Constant	-14.4174*	1.8336
ln(Y/L)	1.5035*	0.2114
ln(FD)	0.1978	0.2110
ln(K/Y)	0.0683	0.1312
ln(PRI)	0.5961*	0.2501
Equation 3	**The Dependent Variable is ln(FD)**	
		S.E.
Constant	-5.0971	3.4382
ln(Y/L)	0.5454	0.3738
ln(RD/Y)	-0.2332	0.2193
ln(inf)	-0.1102	0.0677
ln(Size)	0.1804*	0.0847

* - significant at the 5% level.
Data is averaged over consecutive 5 year periods (1971-1995).

Table 6.3 Panel Estimation of System Equations

The panel results are similar to the findings of the previous cross-sectional regressions. Once again, the R&D variable enters with a positive and significant sign in the primary equation, while the coefficient for financial development is positive but insignificant. The coefficient on the (one-period lagged) capital accumulation variable is positive and significant. The value of the structural parameter on R&D intensity, κ; falls to approximately 0.16, which is less than that resulting from the cross-sectional regressions reported in Table 6.2. In the second equation, which attempts to explain cross-country variations of R&D intensity over the period, financial development is positive but not statistically significant.

The addition of a time trend is necessary when moving from simple cross-sectional analysis, to panel regressions. In both the neoclassical and augmented Schumpeter-Solow equation, the coefficient on this variable represents the world growth rate, which is estimated here to be 5 percent. More specifically, it represents the growth rate of world knowledge.

In the last equation in the system, in which financial development is the dependent variable, the coefficients on inflation and financial market size enter with the expected signs; however, only the latter is statistically significant. Given pervious empirical studies, e.g., Levine et al. (2000), it is posited here that market size reflects the net impact of government financial-specific policies. Larger financial markets, as measured by the amount of private lending and stock market capitalization normalized by GDP, reflect the relative state of financial liberalization or repression. The regression results support the view that liberalized financial systems are better able to lower financial transaction costs associated with funding new projects.

Townsend (1996), in a critical evaluation of Microfinace as a tool of development, associates this view of the importance of financial liberalization and market orientation with the Ohio State school of thought. This characterization is only partially accurate. For an interesting discussion of the evolution of finance's role in development and related policy issues, see Gonzalez-Vega (1993). The finding of a positive link between liberalization and financial development, as defined here, is significant because it responds to one of Townsend's critiques that the Ohio State view lacks substantiation in a dynamic general equilibrium model. In this model, greater liberalization, even in highly sophisticated economies, matters. This finding is most prevalent in the panel results that rely on both cross-country differences and time differences within a country.

The finding of a lower value for structural parameter associated with R&D intensity, reported in Table 3.3, is in need of further explanation. It is likely that five year-averaged data may not be sufficiently long to capture the impact of R&D expenditures on output growth. The findings of Zacharaides (2000) support the view that a longer period of aggregation, despite the loss of some information, is needed to study growth processes.

After further inspection of the data on R&D intensity, it appears that the choice of panel techniques may bias the results towards not finding R&D significant in explaining cross-country differences in per capita income. The various cross-sectional regressions cited above exploit differences across countries (between-group variation).[36] The average variance for R&D intensity, in log form, across countries over the sample period is 0.44, with a maximum value of 0.54 in 1975. In comparison, the average variance of the R&D variable over time for each individual country (in-group variation) is only 0.06, seven times smaller. Additionally this average variation belies the fact that countries already near the technological frontier in 1970 had even less variance in R&D expenditures per income over time. In the case of the U.S., R&D intensity variance is less than 0.005, less than a tenth of the average. These observations support the posited mechanism behind the process of club convergence, namely technological spillovers. Lagging countries, in the club, have an opportunity for "catch-up" as the marginal benefit from technological spillovers fall in leading countries.

In contrast to the purely cross-sectional regressions, panel regressions exploit the time dimension of the data. In the case of the above panel regression, the cross-

[36] The terminology of panel regressions is consistent with Greene (1997).

sectional and the time component of the data are given equal weights. At the other extreme, fixed-effects panel regression techniques rely only on the time variation present in the data. All time invariant country-specific characteristics are swept away. Thus, much of the information of the explanatory variables in the three-equation system is not exploited. The random effects model places different weights on the between-country and in-country (time) components present in the data. For example, one of the regressors in the second equation used to explain R&D intensities is capital intensity, (K/Y). One of the well-known Kaldor stylized facts is the stability of this relationship over time within a country. Thus, capital intensity can provide little insight into the growth process in a fixed effects panel regression.

Not surprisingly, the regression results for the fixed-effects model are perverse in comparison with the previous cross-sectional regressions in this dissertation. In the primary equation, the coefficient on the R&D variable is negative and significant and the regression implies a convergence rate of 1.39 percent, well below other estimates. This shows that over time there is a negative relationship between R&D intensity and the level of per capita GDP with in individual countries in the sample. This is consistent with evidence of club convergence among the OECD countries. The technological leader in 1970, the U.S., falls to 3rd place in terms of R&D intensity by 1995. It is interesting to note that the cross-country variance is also declining over time, falling to under 0.30 by the last period of the study.

Based on the above results, the standard neoclassical growth regressions with exogenous technical progress overstate the role of capital accumulation in explaining cross-country differences in per capita income. The values associated with these structural parameters are reduced with the inclusion of R&D intensity in the regression. In turn, controlling for endogenous institutional change further reduces omitted variable biases. Each of the regression findings provide support for both the Schumpeterian hypothesis that innovation is important in understanding growth and the Northian hypothesis that endogenous institutional change impacts the level of innovations in a society.

Policy Implications

As determined above, innovation as captured by R&D intensities, helps explain cross-country income differences among OECD countries. This supports the Schumpeterian hypothesis that the process of "creative destruction" is the engine of growth in the steady state as well as during convergence to a steady state growth path. In this framework of R&D-lead growth, it is possible for government action to positively impact the level of per capita income, unlike the neoclassic paradigm.

The results from the simple panel regression demonstrate that an increase in the index of patent rights (PRI) increases the level of R&D intensity. The index enters with a lag of one period, five years, to control for the joint-determination of the two variables. Clearly, government should seek ways to improve and strengthen intellectual property rights (patents) of successful industrial entrepreneurs, as a means to increase R&D intensity levels.

However, most policy debates have focused on the use of government subsidies to industrial entrepreneurs. The argument in favor of subsidies focuses on the non-rival nature of a new idea, which leads to positive externalities. Since each idea is only partially excludable, entrepreneurs will likely underinvest in R&D when compared to the social optimum. Although some form of government subsidies are in place in most countries, many questions remain concerning the efficiency of current practices, especially the use of targeted and *ex ante* subsidies exist. See Aghion and Howitt (1998a) for discussions of the key issues involving the controversies of the use of R&D subsidies. Fortunately, the regression results reported above point to a simpler channel, through which policy makers may be able to impact the level of R&D intensity.

In the second of the three simultaneous regression equations, in which R&D is the dependent variable, we have seen that financial development enters with a positive and economically significant value. This provides evidence that financial development by lowering transaction costs associated with funding entrepreneurs, increases the flow of resources into R&D. Governments, that seek to increase long-term output levels by encouraging greater flow of resources into the search for a better industrial blueprint may be able to “liberalize” their financial systems or reduce government-induced impediments to financial exchange. In the United States, removal of branch banking restrictions and the end to “Q-type” interest rate ceilings are examples of such reforms. More generally, the improved definition of financial property rights and enforcement of financial contracts will lower transaction costs.

The use of government loan guarantees or direct financing has been reviewed in the literature. This form of market intervention suffers from the same problem as the use of targeted subsidies; governments are responsible for picking future winners and allocating resources. Such interventions are not supported here. Although not explicitly modeled, the ability of the government to ensure transparent, fair financial transactions plays a large role in ensuring the efficiency of financial innovation.

Extensions

The traditional measures of financial development have largely been based on the relative size of financial markets. Finding a suitable measure for finance has long presented a challenge to researchers. King and Levine (1993a,b) test four different measures of financial depth, including liquid liabilities and bank loans issued to the private sector. Following this tradition, Levine et al. (2000) broaden measures of the size of the intermediated market by including the lending of non-bank intermediaries.

Levine and Zervos (1998) demonstrate the importance of measures associated with equity markets size and activity.

However, measures of the market size of intermediated funds or stock market capitalization do not sufficiently capture the change in transaction costs associated with the marginal borrower brought on by change in financial arrangements.[37] For example, in the U.S., the creation of new financial arrangements associated with venture capital market, have clearly impacted innovation but are not included in the broad measures of intermediation.[38]

Additional financial innovations both in direct and indirect finance range from new financial engineered securities or derivatives to the growth of broker-based direct exchange or swaps. The latter category of innovations include trade of financial and real contracts aimed at risk reduction, e.g., foreign exchange and debt swaps and future contracts based on the outcome of a variety of states of nature, including the weather. One of the common features of such innovations is that few of these financial products are traded on formal exchanges nor are most firms, which serve as intermediary or broker, required to publicly report data on the volume or types of

[37] In the fully augmented regression equation using cross-sectional date, the traditional measures failed to enter either of the first two equations with statistical significance and often changed the sign of the R&D variable in the Schumpeter-Solow equation. The alternative measures are the size of the market used as a proxy of financial liberalization, the size of the stock market relative to the level of intermediation, and the measure of financial "activity" used in Beck and Levine (2001).

[38] According to Gompers and Lerner (1998), entrepreneurial firms, with only intangible capital assets are unable to borrow from traditional sources due to variable and uncertain prospects and the existence of large information asymmetries.

such contracts nor are they subject to stringent oversight as the banking system.[39] For an interesting discussion of financial innovation and its implication for monetary policy see O'Sullivan (2002).

The measure of financial development employed in this dissertation, banking system efficiency, is still based on broad measures of formal markets and thus suffers from some of the same limitations as the traditional size proxies. Specific measures of transaction costs would likely improve the regression results described above. Potential improved proxies for financial transaction costs include the spread between bank deposit and lending rates or the wedge between a firm's internal and external costs of funds. Development of such spread data has been difficult across a wide group of countries. See Beck et al. (2000) for description of a new series of banking data beginning in 1992, which may be more consistent with a transaction costs approach. The improvement of measures of financial transaction costs would greatly enhance the effectiveness of future policy initiatives adopted to increase the level of R&D.

Non-OECD Countries

Perhaps the greatest potential for adding to our understanding of the growth processes

[39] The increasing complexity of financial innovations may outstrip the legal environment's ability to ensure transparency and limit opportunistic behavior of the broker or intermediary.

lies in the re-integration of the insights of economic growth and development. In previous investigations of growth, non-OECD countries have been shabbily treated; they have either been ignored or used as fodder (for additional degrees of freedom) in very broad cross-sectional growth studies. From Mankiw et al. (1992) to Levine et al. (2000), many of the studies in the growth literature include a large number of LDCs in country samples. A simple comparison of most data series of interest show that there is obviously a huge divide between the two major sets of countries. Thus, the finding that capital accumulation or financial development "explains" the differences between countries, e.g., the U.S. and Mali, is not surprising.

It is possible to recast the Aghion-Howitt framework in order to study the diffusion of new ideas. Recall that even spillovers or technology transfers do not occur without costly effort and time. Therefore, it may be reasonable to assume that countries far from the technological frontier do engage in innovative activities, but these activities are related to the adoption of foreign ideas for local productive use. Unlike the serendipitous imitation of a domestic idea employed in Aghion and Howitt (1998a), incorporation of an external blueprint into local production requires R&D expenditures. In this theory of diffusion, such activities would not impact the world's stock of knowledge.

This recommended extension does not advocate the use of broad cross-country regressions, but rather it suggests the analysis of growth using groupings of non-

OECD countries. Desdoigts (1999) provides some direction in group or club formation outside the OECD. The single most significant impediment to this new analysis is, of course, the availability and quality of the data for the potential LDCs sample. Of all the data necessary to test the institutionally augmented Solow-Schumpeter equations, measuring levels of innovation proves to be the most difficult. While some studies, e.g. Lichtenberg (1993), have employed measures of R&D intensity, the quality of this data is quite suspect. A means to capture the local innovation aimed at adopting a new idea is needed.

It will likely be very difficult or impossible to measure the expenditure of real resources on the adoption of ideas. Instead, measures that capture the flow of ideas that serve as the stimulus to local innovation may serve as proxy. The linkage between trade and technological spillover by Coe and Helpman (1995) and Eaton and Kortum (2000) should provide a starting point. The World Bank publishes data on the direction of trade between individual countries and between countries and a group of industrial countries. These data may allow an extension of this research to non-OECD countries. Countries with high levels of imports from countries at or near the technological frontier may spend more resources on the adoption of new blueprints. Another possible proxy for the level of technical transfers is the level of direct foreign investment (DFI).

BIBLIOGRAPHY

Abramovitz, Moses. "The Search for the Sources of Growth: Areas of Ignorance, Old and New." Journal of Economic History. 53(2), June 1993, 217-243.

Aghion, Phillippe and Peter Howitt. "A Model of Growth Through Creative Destruction." Econometrica, 60, March 1992, 323-351.

Aghion, Phillippe and Peter Howitt. Endogenous Growth Theory. Cambridge, MA: MIT Press, 1998.

Aghion, Phillippe and Peter Howitt. "Capital Accumulation and Innovation as Complementary Factors in Long-Run Growth." Journal of Economic Growth, 3(2), June 1998, 111-130.

Ahn, Sanghoon and Philip Hemmings. "Policy Influences on Economic Growth in OECD Countries: An Evaluation of the Evidence." OECD Economic Department Working Paper. No. 246, 2000.

Barro, Robert J. " Economic Growth in a Cross Section of Countries." Quarterly Journal of Economics. 106 (2), May 1991, 407-443.

Barro, Robert J. and X. Sala-I-Martin. Economic Growth. New York: McGraw-Hill, 1995.

Barro, Robert J. and Jong-Wha Lee. "International Measure of Schooling Years and Schooling Quality." American Economic Review, Papers and Proceedings. 82 (2) 1996, 218-23.

Bassanini, Andrea, Stefano Scarpetta, and Philip Hemmings. "Knowledge, Technology, and Economic Growth." OECD Economic Department Working Paper. No. 259, 2000.

Bassanini, Andrea, Stefano Scarpetta, and Philip Hemmings. "Economic Growth: The Role of Policies and Institutions." OECD Economic Department Working Paper. No. 283, 2001.

Beck, Thorsten, Asli Demirguc-Kunt, and Ross Levine. "A New Database on Financial Development and Structure." World Bank Policy Research Working Paper. No. 2146. 2000.

Beck, Thorsten and Ross Levine. " New Firm Formation and Industry Growth: Does Having a Market- or Bank-Based System Matter?" Mimeo, World Bank, May 2000.

Bencivenga, Valerie R. and Bruce D. Smith. "Financial Intermediation and Endogenous Growth." Review of Economic Studies. 58, 1991, 195-209.

Bencivenga, Valerie R. and Bruce D. Smith. "Economic Development and Financial Depth in a Model of Costly Financial Intermediation." Research in Economics. 52, 1998, 363-386.

Benhabib, Jess and Mark M. Spiegel. "The Role of Financial Development in Growth and Investment." Journal of Economic Growth. 5, December 2000, 341-360.

Bodenhorn, Howard. "An Engine of Growth: Real Bills and Schumpeterian Banking in Antebellum New York." Explorations in Economic History, 36, 1999, 278-302.

Boyd, John H. and Edward Prescott. "Financial Intermediary-Coalitions." Journal of Economic Theory. 38, 1986, 211-232.

Boyd, John H. and Bruce D. Smith "The Evolution of Debt and Equity Markets in Economic Development." Economic Theory. 12, Spring 1998, 519-560.

Boyd, John H. Ross Levine, and Bruce D. Smith. "The Impact of Inflation on Financial Sector Performance." Journal of Monetary Economics. 47, 2001, 221-248.

Cameron, Rondo. Banking in the Early Stages of Industrialization. New York: Oxford University Press, 1967.

Clague, Christopher, Philip Keefer, Stephen Knack, and Mancur Olson. "Contract-Intensive Money: Contract Enforcement, Property Rights, and Economic Performance." Journal of Economic Growth. 4, June 1999, 185-211.

Coe, David T. and Elhanan Helpman. "International R&D Spillovers." European Economic Review. 39, 1995, 859-97

Davis, Lance E. and Douglas C. North. Institutional Change and American Economic Growth. London: Cambridge Press, 1971.

DeLong, J. Bradford. “Cross-Country Variations in National Economic Growth Rates: The Role of ‘Technology’.” Mimeo, University of California at Berkeley, May 1996.

Desdoigts, Alain. “Patterns of Economic Development and the Formation of Clubs.” Journal of Economic Growth. September 1999, 305-330.

Diamond, Douglas W. “Financial Intermediation and Delegated Monitoring.” Review of Economic Studies. 53 (6), July 1984, 393-414.

Easterly, William and Ross Levine. “It’s Not Factor Accumulation: Stylized Facts and Growth Models. World Bank Economic Review. (forthcoming).

Eaton, Jonathan and Samuel Kortum. “International Technology Diffusion: Theory and Measurement.” International Economic Review. 40(3) August 1999, 537-570.

Evans, Paul. “Using Cross-Country Variances to Evaluate Growth Theories.” Journal of Economic Dynamics and Control, 20 (6-7), June-July 1996, 1027-49.

Fry, Maxwell J. Money, Interest, and Banking in Economic Development. Baltimore: The Johns Hopkins Press, 1988.

Gertler, Mark. “Financial Structure and Aggregate Economic Activity: An Overview.” Journal of Money, Credit, and Banking, 20, August 1998, 559-88.

Ginarte, Juan C. and Walter G. Park. “Determinants of Patent Rights: A Cross-National Study.” Research Policy. 26, 1997, 283-301.

Gittleman, Maury and Edward N. Wolff. “R&D Activity and Cross-Country Growth Comparisons.” Cambridge Journal of Economics. 19, 1995, 189-207.

Gonzalez-Vega, Claudio. “Comment on Lewis J. Spellman, ‘Economic Growth and Financial Intermediation.” in Ronald I. McKinnon, ed., Money and Finance in Economic Growth and Development. New York: Marcel Dekker, Inc. 1976, 23-34.

Gonzalez-Vega, Claudio. “Credit-Rationing Behavior of Agricultural Lenders: The Iron Law of Interest Rate Restrictions.” in Dale Adams, Douglas Graham, and J.D. Von Pischke, eds., Undermining Rural Development with Cheap Credit. Boulder, CO: Westview Press, Inc. 1984, 78-95.

Gonzalez-Vega, Claudio. “ From Policies, To Technologies, To Organizations: The Evolution of the Ohio State University Vision of Rural Financial Markets.” Economics and Sociology Occasional Paper. No. 2062, May 1993

Gonzalez-Vega, Claudio. "Nonbank Institutions in Financial Sector Reform," in Alison Harwood and Bruce L.R. Smith, eds. Sequencing? Financial Strategies for Developing Countries. Washington, DC: Brookings Institution Press, 1997, 127-146.

Greene, William H. Econometric Analysis. Upper Saddle River, NJ: Prentice-Hall, Inc., 1997.

Greenwood, Jeremy and Boyan Jovanovic. "Financial Development, Growth, and the Distribution of Income," Journal of Political Economy. 98(5), 1990, 1076-1107.

Greenwood, Jeremy and Bruce D. Smith. "Financial Markets in Development and the Development of Financial Markets," Journal of Dynamics and Control, 21(1), January 1997, 145-186.

Grilliches, Zvi. "Comment on Frank R. Lichtenberg, 'R&D Investment and International Productivity Differences." in H. Giersch, ed., Economic Growth in the World Economy. Tuebingen, Germany: J.C.B. Mohr, 1993: 111-113.

Grossman Gene M. and Elhanan Helpman. Innovation and Growth in the Global Economy. Cambridge, MA: MIT Press, 1991.

Gurley, John G. and E.S. Shaw. "Financial Aspects of Economic Development " American Economic Review, 45(3), September 1955, 515-538.

Holmstrom, B. and Jean Tirole. "Market Liquidity and Performance Monitoring." Journal of Political Economics. 101, 1993, 678-709.

Hall, Robert E. and Charles I. Jones. "The Productivity of Nations" NBER Working Paper Series. 5812, November 1996.

Howitt, Peter. "Endogenous Growth and Cross-Country Income Differences." American Economic Review. September 2000.

Jones, Charles. "R&D Based Models of Endogenous Growth." Journal of Political Economy, 103, 1995, 760-784.

King, Robert G. and Ross Levine. "Finance and Growth: Schumpeter Might Be Right." Quarterly Journal of Economics, 108(3) 1993, 717-738.

King, Robert G. and Ross Levine. "Finance, Entrepreneurship and Growth: Theory and Evidence." Journal of Monetary Economics, 32, 1993, 513-542.

Levine, Ross and David Renelt. "A Sensitivity Analysis of Cross-Country Growth Regressions." American Economic Review. 82, 1992, 942-63.

Levine, Ross. “Financial Development and Economic Growth: Views and Agenda,” Journal of Economic Literature. 35, June 1997, 688-726.

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

Levine, Ross. “The Legal Environment, Banks, and Long-Run Economic Growth.” Journal of Money, Credit, and Banking, 30(3), August 1998, 596-613.

Levine, Ross, Norman Loayza, and Thorsten Beck. “Financial Intermediation and Growth: Causality and Causes,” Journal of Monetary Economics. 46, August 2000, 31-77.

Lichtenberg, Frank R. “R&D Investment and International Productivity Differences.” in H. Giersch, ed., Economic Growth in the World Economy. Tuebingen, Germany: J.C.B. Mohr, 1993: 89-110.

Mankiw, N.G., David Romer and D.N. Weil. “A Contribution to the Empirics of Economic Growth.” Quarterly Journal of Economics, 107(2) 1992: 407-437.

McGrattan, Ellen R. and James A. Schmitz. “Explaining Cross-Country Income Differences.” Research Department Staff Report 250, Federal Reserve Bank of Minneapolis, August 1998.

McKinnon, Ronald I. Money and Capital in Economic Development. Washington DC: Brooking Institution, 1973.

Nardiri, M. Ishaq. “Innovations and Technological Spillovers.” NBER Working Paper Series 4423, August 1993.

North, Douglass C. Structure and Change in Economic History. W.W. Norton , New York, NY, 1981.

North, Douglass C. “Institutions and Economic Growth: An Historical Introduction.” World Development. 17(9), 1989, 1319-1322.

North, Douglass C.. “Institutions.” Journal of Economic Perspectives. 5(1) 1991, 97-112.

North, Douglass C.. “The New Institutional Economics and Third World Development.” in John Harris, Janet Hunter, Colin Lewis, eds., The New Institutional Economics and Third World Development. Routledge, London. 1995.

North, Douglass C.. and Robert Paul Thomas. “An Economic Theory of the Growth of the Western World.” The Economic History Review. 23(1), 1970, 1-17.

O’Sullivan, Roisin. “Financial Innovation and Monetary Policy.” Mimeo, The Ohio State University, June 2001.

Quah, Danny T. “Twin Peaks: Growth and Convergence in Models of Distribution Dynamics.” The Economic Journal. 106 (437), July 1996, 1045-1055.

Romer, Paul M. “Endogenous Technical Change” Journal of Political Economy, 94, 1990, 1002-1037.

Rosenberg, Nathan. Inside the Black Box - Technology and Economics. Cambridge: Cambridge University Press, 1982.

Rousseau, Peter L. “The Permanent Effects of Innovation on Financial Depth: Theory and U.S. Historical Evidence from Unobservable Components Models.” Journal of Monetary Economics. 42, 1998, 387-425.

Rousseau, Peter L. and Richard Sylla. “Emerging Financial Markets and Early U.S. Growth.” NBER Working Paper Series. 7448. December 1999.

Schumpeter, Joseph A. Theory of Economic Development. Cambridge MA: Harvard University Press, 1934.

Schumpeter, Joseph A. Capitalism, Socialism, and Democracy. New York: Harper & Brothers Publishers, 1942.

Shaw, Edward S. Financial Deepening in Economic Development. New York: Oxford University Press, 1973.

Smith, Bruce D. “Informational Asymmetries in Macroeconomics and Finance: An Introduction.” Economic Theory. 12, Spring 1998, 451-460.

Summers, Robert and Alan Heston. “The Penn World Tables (Mark5): An Expanded Set of International Comparisons, 1950-1988.” Quarterly Journal of Economics. 106 (2), May 1991, 327-303.

Townsend, Robert M. “Optimal Contracts and Competitive Markets with Costly State Verification.” Journal of Economic Theory. 21, 1979, 265-293.

Townsend, Robert M. “Microenterprise and Macropolicy.” in David M Kreps and Kenneth F. Wallis, eds., Advances in Economics and Econometric: Theory and Applications. Cambridge: Cambridge Press, 1997, 160-209.

Zachariades, Marios. “R&D-induced Growth? Evidence from the U.S. Manufacturing Sector.” Mimeo, Louisiana State University, November, 2000.