YEDITEPE UNIVERSITY INSTITUTE OF SOCIAL SCIENCES

THREE ESSAYS ON ECONOMIC GROWTH :

FINANCIAL INNOVATION, HUMAN CAPITAL AND FOREIGN DIRECT INVESTMENT

AHMET CEMİL BORUCU

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BY

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Ahmet Cemil Bozca

ABSTRACT

The most recent global financial crisis has fueled arguments against financial innovation on the premise that it was especially the financially engineered complex products that triggered or paved the way to the crisis, which had detrimental effects on macroeconomic growth. Thus, there is considerable motivation to study and empirically test financial innovation and GDP growth relationship. In chapter 1, focus is to examine financial innovation and GDP growth relationships within an endogenous growth model. I explicitly aim to derive balanced growth path equilibrium and stability conditions for the endogenous growth model. Genuine proxy variable for financial innovation is defined. Also an iterative estimation technique panel nonlinear least squares method with Gauss Newton algorithm is used to determine relation between per capita growth and financial innovation via simulation. In chapter 2 and 3, we aim to test whether the nonlinear endogenous growth model explains relationship between per worker growth and other important growth determinants namely Human Capital and Foreign Direct Investment and also compare and contrast Financial Innovation empirical results with them.

ÖZET

Son küresel finans krizi sonrasında finansal inovasyonun olumsuz sonuçları hakkındaki tartışmalar alevlenmiştir. Zira, finansal mühendislikle yapılandırılan karmaşık ürünlerin makroekonomik büyüme üzerinde çok olumsuz etkileri olan krizi tetiklediği görüşü hakim olmuştur. Bu nedenle finansal inovasyon ile büyüme arasındaki ilişkinin araştırılması ve ampirik olarak test edilmesi için yeterli motivasyon mevcuttur. Çalışmanın birinci bölümünde finansal inovasyon ile büyüme arasındaki ilişkinin endojen büyüme modeli çerçevesinde incelenmesi hedeflenmektedir. Büyüme modelinin denge noktası ve kararlılık koşulları belirlenmektedir. Finansal inovasyon için mevcut literatürde kullanılmamış, yeni bir değişken tanımlaması yapılmıştır. Ampirik çalışmada finansal inovasyon ve kişi başına gelir büyümesi arasındaki ilişkinin belirlenmesi için, panel veri doğrusal olmayan en küçük kareler yönteminde gauss newton algoritması kullanılarak iteratif simülasyon gerçekleştirilmiştir. İkinci ve üçüncü bölümlerde doğrusal olmayan endojen modelin büyüme ile Beşeri Sermaye ve Doğrudan Yabancı Sermaye Yatırımları arasındaki ilişkiyi açıklayıp açıklamadığı ve ayrıca Finansal İnovasyon değişkeninin empirik sonuçlarıyla karşılaştırma yapılması hedeflenmektedir.

To my wife Deniz, my father Bekir Sıtkı and my sister Ayşen without whose support completing this thesis would not have been possible. I also would like to thank EviewsGlenn and all other members from the Eviews® forums support team for providing feedback to my persistent requests regarding programming and other issues on technicalities.

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ABSTRACT

The aim of this chapter is to empirically test whether financial innovation stimulates macroeconomic growth, within an endogenous growth model using a genuine proxy variable for financial innovation. In order to stimulate theoretical framework for the empirical part, explicit derivation of endogenous macroeconomic model dynamics, balanced growth path equilibrium, stability conditions and also convergence coefficient are presented. Numerous examples for financial innovations along with a genuine definition of Financial Innovation proxy variable, as far as current literature is concerned, is provided. Empirical estimation results for panel data comprising of 11 OECD member countries through the years 1991 – 2009 via nonlinear least squares method and also simulation results are given. We find statistically significant and negative relation between our proxy variable for financial innovation and per capita growth, indicating that higher financial innovation is associated with higher macroeconomic growth.

Keywords : Financial Innovation, Endogenous Growth Model, Convergence, Balanced Growth Path, Panel Nonlinear Least Squares, Gauss Newton Algorithm (GNA), Simulation

1. Introduction and Literature Review

It would not be wrong to state there is a consensus among economists that two major factors are driving long run economic growth: Labor Efficiency and Capital Intensity. Efficiency of Labor is fueled by advances in technology and organization of the production processes. Capital Intensity is measured by ratio of capital to per unit output. Higher capital intensity implies more productive economy. Technology and process organization advances are key drivers of labor efficiency while saving and investing are drivers of capital intensity.

(Schumpeter, 1939) defines an innovation as a change in the production function and categorizes them as either a process innovation or product innovation. Process innovation enable existing product or service to be provided more cheaply. Product innovation provides a genuine product or service that was not available previously. In practice there exist innovations which combine both characteristics. For example ATM (Automated Teller Machine) provides routine banking services like withdrawal/deposit of money less costly. Cost reduction feature of financial innovation is generally seen as a result of technological change i.e. advances in computing power and miniaturization.

(Merton, 1992) states that the primary function of the finance sector is to foster allocation and widespread use of economic resources, both dimentionally across market players and across time in an environment which entails risks from uncertainity. (Frame & White, 2004) add that, this function also includes establishing and maintaining a payments system which enables transfer of financial assets from saving entities to investors and also the repayment process at maturity. Moreover gathering of savings for the purposes of pure consumption, and also risk mitigation through diversification and insurance. The operation of financial system includes labor and capital inputs/costs which are reflected in pricing of services provided to customers. From this perspective financial innovation is something genuine and when applied results in cost reduction, risk reduction or a method/process which supplies product/service in an improved way that better meets the needs of customers.

(Frame & White, 2004) examine empirical studies of financial innovation. In their words while using relaxed criteria, the authors find two dozen studies over half of which were conducted since the year 2000. Within these studies 14 were identified as distinct innovations. They stress that number of research papers which empirically test hypotheses concerning financial innovation is surprisingly few. Authors take this issue to the attention of financial regulators and urge them to design more compulsory surveys about financial innovation and to make results of the survey data open to academic researches so as to proliferate empirical studies on this topic.

In support of above statements (Volcker, 2009) former Chairman of the Federal Reserve has been quoted as follows ;

“I wish someone would give me shred of evidence linking financial innovation with a benefit to the economy”.

(Gennaioli, Shleifer, & Vishny, 2011) develop within a in a pure exchange economy setting, a rational expectations model of financial innovation. Their model is formed in support of the idea that investors increasingly demand safe cash flow instruments and in response, financial intermediaries through financial innovation/engineering supply products where there are inherent neglected risks present. But through diversification, tranches, insurance and other financial engineering methods, these products are believed by investors and also maybe by issuers themselves to be low risk and thus supplied in large scale volumes, whereby increasing financial fragility. Resembling the recent financial crisis, at some point inherent risks are realized triggering a financial crisis. They propose that regulatory policy formulations should not just focus on controlling leverage and fire sales, but also the scale of financial innovation and demand triggering it should also be attended. As an example they propose that innovation of prime money market funds which are invested in risky securities can be marked to market.

(Chava, Oettl, Subramanian, & Subramanian, 2013) examine effects of banking sector deregulation on economic growth, through building on the premise of endogenous growth theory. They proxy firm innovation by number of patents of United States companies within United States Patent and Trademark Office (USPTO) and also number of citations to these patents within NBER Patents File. Nonlinear exponential model specification is used for empirical testing, where fixed effects Poisson estimator is employed. They conclude that intrastate deregulation resulting in higher local market power for local banks, decreases innovative activity of young, private companies. On the contrary, interstate deregulation which decreases market power of local banks, boosts innovative activity of young, private companies.

(Michalopoulos, Laeven, & Levine, 2014) examine interaction of finance and technology through incorporating not only technological, but also financial innovation in their endogenous growth model. Moreover they define “financial entrepreneurs” who invest in activities which improve screening of technological entrepreneurs. They posit that successful financial innovation provides asymmetric information screening ability and thus profit for financiers. In their model, financial innovation is defined as growth rate of ratio of private credit to GDP. Also the year in which a country developed a credit bureau to share information about borrowers is defined as an additional financial innovation measure. In the empirical study, they use linear specification for panel data and use GMM estimator to examine impact of financial innovation, financial development and other growth determinants on growth rate of per capita income. Results show positive and statistically significant relation between financial innovation and growth. Moreover they also conclude that introduction of a private credit bureau (as a proxy for financial innovation), fosters faster convergence of less developed economies to the growth levels of advanced economies.

(Beck, Chen, Lin, & Song, 2016) use R&D expenditure data for financial intermediation industry as Financial Innovation proxy, which is supplied by Analytical Business Enterprise Research and Development Database (ANBERD). They claim to be the first to use R&D expenditure based financial innovation data. They specify linear relationship between GDP growth and interaction variable defined for global growth opportunities and financial innovation. Also in the same study they also specify a linear relationship between GDP growth volatility (defined as standard deviation annual growth rate of value added) and financial innovation. OLS and also GMM estimators are used on bank, industry and country level data for 32 countries. As a result they conclude that positive and significant relationship exists between, global growth opportunities of a country and higher level of financial innovation and GDP growth. But on the other side they also find that higher level of financial innovation is associated with higher growth volatility in industries which utilize high debt financing and depend more on R&D activity. Therefore they find evidence supporting pro and cons of financial innovation.

The aim of this chapter is to empirically test whether financial innovation stimulates macroeconomic growth within an endogenous growth model using a genuine proxy variable for financial innovation. Moreover we specify a nonlinear model in our empirical study that also differs from existing financial innovation and growth research literature which has been reviewed. In order to stimulate theoretical framework for the empirical part, explicit derivation of endogenous macroeconomic model dynamics, convergence coefficient and transitional stability conditions is presented initially.

1.1. Financial Innovation Examples :

In order for the concept to be more concrete, a number of Financial Innovation examples are presented below. While the list may not be comprehensive, it provides an overview of how financial innovation has evolved throughout modern history. We consider keeping in mind the definition made by (Schumpeter, 1939) to be beneficial, so as to evaluate characteristics of different types of financial innovations.

1.1.1. Automated Teller Machines (ATM):

ATM's have been designed to provide banking services like money deposit, withdrawals, transfers, account statements offsite and 7/24, and less costly. The first ATM was operational as of 27 June 1967 at Barclays Bank Enfield/London branch.

1.1.2. Credit Cards / Installment Credit Cards:

This financial instrument has been designed to enable cardholders to pay for goods and services either with or without instalments. Credit cards are issued by banks which are linked to an account for which a credit line is assigned. Cardholder is free to make purchases from merchants or directly withdraw cash advance from an ATM. Of course credit card product specifications are different from debit cards, where amounts purchased or withdrawn are directly debited to your account balance and the amount of cash money balance in your account is the assigned limit. Moreover one can make partial payments of amount due every month, rather than pay all against a charge of interest.

1.1.3. Crowd Funding:

Company gains access to finances through public offering of small portions of equity to a mass market of investors. This is depicted as a genuine type of investment banking functioning through a website. Small investors can buy shares through the website. www.kickstarter.com, www.peerbackers.com are two examples providing crowdfunding solutions. (Shiller, 2013)

1.1.4. The Benefit Corporation:

Benefit Corporations are a new type of corporation defined in commercial law and commits officially to perform for the good of the society as well as pursuing profit maximization. Since they are officially charged with these goals, stakeholders will not be pressurizing executive management to exercise against these goals. It provides company with a very high social reputation and violating it poses a high risk. These companies are periodically assessed by public bodies or publicly certified firms, to ensure they are holding the credentials of a benefit corporation. Fertilizer producer Grower's Secret states to protect phosphorous, potassium and nitrogen equilibrium within oceans since fertilizers are mixing into the oceans to start chemical reactions that are harmful. This benefit corporation mission is to address this environmental problem while also pursuing profits.

1.1.5. The Social Impact Bond:

This financial instrument is not a conventional bond such that, although there is a fixed maturity, there is no fixed interest and capital return. The bond issuer pays back to creditors conditional on the fulfillment that pre-determined social and environmental goals are met. The underlying motivation is to have free market enterprise contribute to remedying an environmental or social problem. (Shiller, 2013)

1.1.6. Securitization:

As a financial innovation, securitization aims to mitigate negative impact of asymmetric information through assigning a credit rating to underlying assets and also to resolve capital adequacy ratio constraints on bank balance sheets. Examples are mortgage backed securities which are analyzed by professional analysts requiring much technical expertise that cannot be performed by individual investors. Securitization has played a role of conduit to the market without which investor demand would not have been in material amounts. Thus securitization facilitates financial market making that allows many people to buy houses, through increased supply of funds and lower interest rates.

1.1.7. Venture capital companies:

Venture capital has evolved as a prominent intermediary in financial markets, through investing capital to entrepreneurs who do not have access to necessary financing, due to issues such as being a startup company. Finance demanding firms are typically startups or companies having few years of track record. Moreover, they possess very few assets eligible for collateral and possess high risk in terms of going concern principle. Venture capital firms are the financiers of these firms with typically high risk, and if successful have high return operating model. They finance through buying a stake in their equity and/or equity-linked stakes. Key financial innovation of venture capital firms is their ability to invent genuine methods to assess, value and monitor true financial state and future prospects of these firms, given limited and asymmetric data and market conditions.

(Gompers & Lerner, 2001) state that high uncertainty and asymmetric flow of information to the investors are typical shortcomings for new startups, especially in Information Technology oriented sectors. The fundamental concerns of investors would be cases where managers are prompted to channel outside financing to inefficient activities such as highly expensive offices due to lack of corporate governance. Moreover managers may continuously increase outside borrowed debt, disproportionate to company size without the investors approving or knowing up front (Jensen & Meckling, 1976). Practical difficulties such as inability to monitor company results and outcomes effectively and with utter confidence would imply inability to draft legally binding comprehensive term sheet for the financing. All these issues lead to same result, which is that these firms which rely heavily on intangible assets, Information Technology and R&D activities are very hard to assess in terms of their performance. Due to lack of transparency and corporate governance, entrepreneurs might channel firm efforts to projects that might bring high recognition to owner but losses for all the other shareholders. The key idea here is that the entrepreneur is investing through inputting ideas, but the financial investment is done by financing firms, since the owner does not posses necessary funds and this eventually poses high risk for the investor. This leads to an outcome where external equity or debt financing for these startup of young firms is scarce, costly or difficult to obtain. Venture capital organizations, overcome these barriers which make other financing institutions reluctant, by financially innovating. They use techniques such as becoming executive member of board, setting themselves in the hub of information flow, extensive review of information before releasing capital injection and injection of capital in tiers rather than bulk investment, which make them much more flexible than conventional finance firms.

1.1.8. Debit Cards:

A debit card is a plastic payment card that provides 7/24 electronic access to their bank account via ATMs, POS machines. The card, where accepted, can be used instead of cash when making purchases. In many countries, debit card transactions dominate and replace cheques and sometimes cash transactions. Debit card payments are instantly debited to cardholders account and credited to seller/merchant account and if no additional overdraft limit is assigned, then one can purchase only up to account balance amount. So the payment from cardholder is made immediately rather than after a cutoff date, which is the case for credit cards.

1.1.9. Electronic Bill Payment Services :

Electronic bill payment service is ability to predefine periodic household bill payments to different institutions (i.e. natural gas, electricity, water, cable tv, phone etc.), to the customer’s bank account. The bills are paid automatically on last payment date via internet banking, telephone banking, mobile banking, bank branch feature of online, mobile and telephone banking. Moreover one can also define the same bills to be charged automatically to his/her credit card as well. In order for these payments to be made, financial institutions make formal agreements with bill collecting institutions so that the data regarding due amounts of bills can be obtained electronically and transferred from paying customer’s account to the receiving institutions’ accounts which are opened either at the service providing bank or if not, transferred to another account holding bank via local currency electronic fund transfer IT systems.

This financial innovation provides several benefits for both paying customer and receiving institution. Consumers overcome the burden of following up last payment dates, allocating time to make payments physically at the institution and filing paper work regarding receipts. For receiving institutions, reduced administrative and personnel costs, less fraud risk, immediate access to funds and enhanced cash flow management, less paper work are key benefits. And lastly, service providing banks major benefit is increased customer loyalty, cross sales, increased flow of demand deposit, reduced overhead costs due to less paper work and controls. The main fascilitator of this service for wide spread use is, primarily internet banking.

1.1.10. Overdraft Deposit Accounts :

Overdraft means that account holder withdraws cash from demand account which is higher and above than the outstanding balance. Eventually this implies that account balance becomes negative after money is withdrawn, and so the account becomes overdrawn. The innovation differentiating overdraft deposit account from regular cash loan rests in the fact that no prior documentation is necessary other than one-off signed general account opening agreement, usually without any additional collateral requirements. Overdraft account is a revolving loan. Unlike regular cash loans which are either equal installment or bullet loans with a predefined maturity, revolving loans do not have a pre-set maturity, only interest accrued quarterly should be paid in cash. The innovator of overdraft account is Royal Bank of Scotland at 1728. Historically overdraft account facility is viewed as a positive fueler for startup businesses which did not possess collateral to offer to banks. Scottish philosopher and economist is quoted to have described this financial innovation as "one of the most ingenious ideas that has been executed in commerce".

1.1.11. Financial Derivative Instruments :

Financial derivative instrument is a product which derives its value / price from the value of another financial instrument, commodity or interest rate usually coined with the term underlying. Majority of financial derivative instrument transaction volumes are over-the-counter, but of course are traded on an organized exchange as well. Most well-known financial derivatives are namely forward, futures, options, swaps. There exist quite a number of variations of these derivative instruments like collateralized debt obligations and credit default swaps.

Varying number of uses of financial derivatives solidify their financial innovation attributes;

- "Hedge" or synonymously use it to mitigate financial risk in the underlying asset through buying/selling a financial derivative contract based on underlying contract and whereby the value/price has negative correlation with that of the original risky position.
- Obtain an "option" based on the condition that certain event or condition occurs through which the financial derivative instrument value is derived.
- Gain the ability to take a position/exposure on the underlying asset/interest etc. in conditions where there is no other medium to do so, for example weather derivatives.
- Obtain what is called financial leverage where financial derivative investor invests only a fraction of the underlying, such that a small movement in the underlying value can cause a large difference in the value of the derivative
- Take speculative position on the underlying asset through investing on a financial derivative based on the underlying, where the direction of trade (buy/sell) would indicate the expectation on future movement of the underlying asset. Specifically contract terms typically would be based on, price/value movements in a pre-specified direction or would be in or out of a specified range or if a certain level is reached.

- Ability to avoid taxes whilst taking position on an underlying and profiting. Investing in an equity swap entitles investor to receive fixed payments based on LIBOR rate and at the same time be exempt from capital gains tax.

1.1.12. Credit Bureaus:

Credit bureau is a generic name given to companies that collect financial and related information from on individuals obtaining consumer loans and related products, to process and model it with the ultimate goal of producing a consumer credit score. Of course as a by-product they may also supply the data gathered to financial companies, so that they may also use it in their credit decision processes. A company solely providing data on consumer financial behaviors is called Consumer Reporting Agency. The financial innovation component of Credit Bureau and Consumer Reporting Agency rests in the fact that they foster greater transparency for credit decision making and monitoring during the life of credit and thus remove asymmetric information therein. Past loan payment track record is a very important determinant of expected future payment performance. Then, it is through this financial innovation which provides effective screening and monitoring ability that makes finance sector mass market consumer loans. Moreover through this innovation, risk based pricing is effectively exercised. Of course consumer loan applicants with poor past repayment history will be ranked riskier and thus be approved with higher interest rate. On the contrary consumer’s loan applicants with good repayment history will be charged lower rates and thus financially benefit from this. All this setup made possible by credit bureau financial innovation, provides positive incentive to be loyal to their debt obligations.

Consumer debt payment performance data providers to credit bureaus are creditor financial institutions, collection firms. Consolidated consumer debt payment performance data and also credit score derived from it, is recorded in database and delivered as a service to credit bureau customers.

Equifax Inc. incorporated in 1899, Experian and TransUnion are three largest consumer credit reporting agencies in the United States, whereas Kredi Kayıt Bürosu (KKB) is the monopoly credit bureau institution in Turkey established by banking sector themselves.

1.1.13. Internet Banking :

Internet banking is synonymous with online banking, e-banking, or virtual banking. Basically it is setup as a web based service interconnected to core banking application of service offering banks. Customers registered to internet banking have access to quite a number of banking services such as money transfer, electronic bill payment, credit card, business card services and deposit transactions. This financial innovation is in essence giving customers ability to directly conduct branch operations via internet.

The benefits as an financial innovation is both ways, customers gain time and pay less transaction costs by having direct control over their products, banks / financial institutions lower their overhead costs via reducing load off of branches and thus also staff costs and also build customer loyalty, whilst creating a platform to directly market products and build on their Customer Relationship Management (CRM) efforts.

1.1.14. Telephone Banking :

Telephone banking service can be considered as a more primitive version of internet banking. Basically all the services over the internet banking is provided through a call center personnel over the telephone. The reason why it is still not redundant in the presence of internet banking is that, there exist customers who still need to do certain transactions whilst explaining it to a bank personnel but still wants to save time by not travelling to a physical bank branch. Moreover there are certain services which still need to be verified by bank staff, like setting up new password for internet branch, debit card, credit card or cancelling a credit card reported to be lost or stolen.

Benefits of telephone banking are the same as internet banking; customers gain time and pay less transaction costs by having direct control over their products, banks / financial institutions lower their overhead costs via reducing load off of branches and thus also staff costs and also build customer loyalty.

1.1.15. Credit Monitoring Systems :

Credit monitoring systems are developed by banks, where automated rule sets have been defined for early warning signals for performing loans, assigning relative weights to those early warning signals to reflect on customer credit classification and so determine whether remedial actions to strengthen collateral and/or reschedule payment plan for the loan is necessary or not. The primary objective is to reduce information asymmetry which is ever present about current repayment performance of corporate and consumer loan clients through (Cognizant, 2014):

- Early detection of erosion in the creditworthiness of loan customers,
- Taking immediate remedial action via obtaining additional collateral whilst providing new solutions to ease cash flow problems of loan customers,
- Resort to actions leading to decreasing the exposure of watch list or intensive care customers before default.

Credit monitoring systems are highly IT dependent, due to handling of big data as well as intellectual capital which puts the blueprint as to how to design decision maps, develop credit rating models and credit scorecards which translate into corporate credit policy and shape credit risk appetite of financial institutions.

(Babel, et al., 2012) state that the more late coming a bank is when it comes to detecting and taking remedial action to detoriation in creditworthiness of a client, the probability to incur losses increases proportionally. Moreover banks with effective early warning systems are able to short list detoriating credit customers 7 months earlier compared to those without or those which have ineffective systems.

1.1.16. Electronic Payment Systems :

A national payment system is an electronic fund transfer system that is administered by local central bank and permits efficient, safe transfer of funds between members of the system, which are basically banks. The establishment of such an IT based payment system in fact is what makes interbank, money, and capital markets work effectively. Settlement risk is in effect eliminated since transfers occur “real time". Since no physical exchange of money takes place, cost of transfer of funds is in effect very low.

1.1.17. Railroad company financing:

During 1850's United States witnessed building of very large scale railroads by construction contractors which in turn squeezed out all available credit from households and also financial intermediaries. But since railroad construction required more and more capital which at a point came to a stall as available financial resources were depleted. The solution was to knock on the door of European money markets by the railroad president. But since this financing was to be provided to cross-continent companies, there was hesitation on side of financiers on how to assess creditworthiness and also monitor it during the life of the loan.

In order to effectively screen and also monitor financial position and creditworthiness of railroad companies which built large scale railroads in the 19th and 20th centuries, financial entrepreneurs innovated specialized investment banks and accounting systems like inventing new financial analysis performance indicators. Through innovating this way, they were able to finance distant investors and also monitor them (Chandler, 1965) (Baskin & Miranti, Jr., 1997); (Neal, 1990).

1.2. Theoretical Framework:

1.2.1 Endogenous Growth Model Specification

(Romer P. , Increasing Returns and Long-run Growth, 1986) has shown that through broadening the definition of capital to include knowledge capital or human capital as well, endogenously determined technological change, which is a function of the previous forms of capital, eliminates the neoclassical assumption of decreasing returns to capital. Moreover this specification also voids convergence of growth levels across countries, as was predicted by Solow model. (Lucas, Jr, 1988), (Romer P. , Endogeneous Technological Change, 1990), and (Grossman & Helpman, 1991) specify models that imply higher levels of human capital, through effecting technological change will in turn lead to positive growth rates in the long run whereas on the contrary, lower levels of human capital stock would imply low growth in per capita income. This phenomenon would also explain why we observe non convergence in under developed countries compared to developed ones, contrary to what Solow model predicts, namely unconditional convergence.

In this section I follow (Ulusoy, Trade and Convergence: A Dynamic Panel Data Approach, 2001), (Ulusoy & Yalçın, Convergence of Productivity Levels Among EU Countries : Evidence From A Panel Of Industries, 2011) which builds upon the former study by introducing spillover through international trade and (Karpavicius, Ulusoy, & Yalçın, 2014) which expands the learning-by-doing model in the former study and analyzes empirically the balanced growth path per capita income level distribution and its convergence speed along this path toward, equilibrium.

Within the endogenous growth model, the concept of conditional convergence is also used to depict how each economy grows to reach balanced growth path equilibrium, so as to investigate whether financial innovation assists an economy through the transitional dynamics to it's balanced growth path.

Endogenous growth model utilizes following Cobb-Douglas form production function :

$$Y_{it} = A_{it} K_{it}^{\alpha} L_{it}^{1-\alpha} \qquad \textbf{(1)}$$

where $0 < \alpha < 1$. Subscript i is for country and t is for time period, Y_{it} is output, K_{it} is the physical capital stock, L_{it} is labour force, and A_{it} denotes technology level. Since we are using neoclassical production function, I assume constant returns to scale, or in other words homogeneity of degree one in *K* and *L*. Moreover as indicated in (Romer D. , Advanced Macroeconomics, 1996), the economies are big enough that the gains from specialisation are non existent or immaterial. The second assumption is that other inputs such as land and natural resources are not material compared to capital and labour inputs.

The variable A_{it} measures aggregate output augmenting technological progress for country i at time t. As per (Romer P. , Endogeneous Technological Change, 1990), technology is not a conventional (about physical things) or a public good (provided free of charge). It is a non public and a nonrival good (about ideas) which is also partially excludable (access can be partially limited via patents, copyrights). And once a certain technological advance has been made, it can be applied at any scale of production without having to be reproduced.

We develop technological progress in terms of production function and financial innovation as follows :

$$\dot{A_{it}} = Y_{it}^{\beta 1} {FI_{wit}}^{\phi} {A_{it}}^{\theta} - \gamma A_{it} \qquad \textbf{(2)}$$

$\dot{A}$ denotes derivative with respect to time, FI_{it} is financial innovation for country i and time period t and γ represents depreciation rate of technology. We allow 0 < β1<1, Φ < =1 and 0<θ< 1. Equation (2) implies that the change in technological progress is proportional to total output, financial innovation and the current technology level at date t. Note that in this model, technology as a function is not assumed to have constant returns to scale in its defined inputs, unlike the aggregate production function in equation (1). Technological progress can have diminishing returns or increasing returns since 0 < β1<1, Φ < =1. When gross production level and financial innovation is doubled, overall technological progress may or may not double as well. 0<θ < 1 coefficient reflects the idea that past technological progress also influences current change in technology.

1.2.2 Defining Financial Innovation Variable :

Next step is to define financial innovation variable FI_{it}. (Frame & White, 2004) have surveyed and summarized the existing empirical literature on financial innovation.

They stress that number of research papers which empirically test hypotheses concerning financial innovation is surprisingly few. They offer four reasons as to why this occurs.

First, empirical studies for production sector has proxied innovation with (R&D) research and development activities by companies. They used existence of research laboratories, Research & Development budgets and also number of engineers and scientists. On the contrary financial sector companies do not book R&D budgets, but it may be linked to IT budgets. As a result due to non existence of available conjugate data used in production Empirical testing of hypotheses involving R&D are unlikely to occur in financial services.

Second, some researchers have proxied number of patent applications and number of patents in their studies again, involving non-financial sector. Since financial products and services are not commonly patented or registered formally, empirical examinations of financial innovation using patent counts is unlikely to occur. (Lerner, 2002) who examines patents for financial formulas and methods, is the only study in this field. But then again this study does not examine financial innovation.

Third, data that are commonly used for research about financial services are made available and consolidated at certain resources namely, the Center for Research in Securities Prices (CRSP), and Standard & Poor's COMPUSTAT data files. These sources do not provide data or information about financial innovation.

And fourth, they claim that scientists empirically working on innovation are trained in industrial organization economics who specify Schumpeterian hypotheses: economy's innovation occurs in large firms having significant market power.

This study emphasizes the role of Credit Early Warning Systems as a major financial innovation, since it enables protecting most important asset class and primary revenue source for the majority of the banking system, namely loans to corporate and retail clients. Taking into consideration the limitations mentioned in (Frame & White, 2004) study we define Financial Innovation measure for a country as ratio of Loan Loss Provisions / Total Loans.

$$FI_{wit} = \frac{Provision\ on\ Loans_{it}}{\sum Loans_{it}} \qquad \textbf{(3)}$$

This reflects on the fact that **higher the innovation** in credit early warning systems, banks would detect poor performing loans in a timely manner and provide necessary time to workout the loan without the need to allocate proportionally high amount of provision. This would in turn, lower the loan loss provisions (which are expenses lowering profitability), sustain asset quality and resources available for lending. FI variable can increase either by provisions increasing or total outstanding loans decreasing or both. In reality loans would decrease either in a liquidity crisis in financial sector or if credit risk appetite is decreasing. In both cases theory suggests that overall economy would also be contracting. Lastly if Loan Loss Provisions (LLR) are increasing, then again overall risk appetite of banks would expected to be decreasing and have negative effect on growth again. This definition implies that **higher values of**

FI variable would signal poor monitoring of loans and thus **ineffective/low level of financial innovation** and also **lower economic growth**. On the other hand **lower values of FI** variable would **mean the opposite**. Therefore we expect GDP to move opposite directions with our proxy for financial innovation defined above. But then again increase in financial innovation still would benefit GDP growth positively. Of course we are ruling out cases where banks may be allocating higher than necessary provisions so as to future plan their profit or allocating lower than necessary provisions for loans which are effectively non-performing, having very dire recovery expectations. Since bank financials are subject to external audit and regulatory review, ruling out these and similar cases is a valid assumption.

1.2.3 Laws of Motion for Physical Capital Stock

Next step physical capital stock accumulation is defined in the usual fashion which is gross capital investment minus depreciation on capital :

$$\dot{K_{it}} = I_{it} - \delta K_{it} = sY_{it} - \delta K_{it} \qquad \textbf{(4)}$$

where δ is depreciation rate of capital stock. As in the (Solow, 1956) - (Swan, 1956) model, s is saving rate expressed in percentages assumed to be reinvested in acquiring new physical capital stock. s is a constant determined exogenously in the model. Here we assume a closed economy without public spending G(t) and all production is either allocated to investment I(t) or consumption C(t) so;

$$Y_t = C_t + I_t$$

Amount saved is equal to gross investment.

$$S_t = Y_t - C_t = I_t$$

s(·)is the fraction saved (i.e. saving rate) and 1 – s(·) is fraction consumed. We assume s(·) is given exogenously where 0 < s(·) <= 1. Given saving must equal to investment S(t) = I(t), implies that saving rate equals rate of investment.

Equation (4) shows the laws of motion of physical capital given labor force, L, input into production function Y. With the usual assumption that labor force grows at a constant rate n given exogenously :

$$\frac{\dot{L}}{L} = n \geq 0$$

If we normalize the number of people at time zero to 1 and work intensity per person also to 1, then labor force at time t becomes :

$$L_t = e^{nt}$$

1.2.4 Per Worker Specification

In order to simplify the model by expressing it as a function of fewer variables we express dynamics of physical capital growth in terms of per capita or per worker only.

Along with the simplificiation, note that this produces economically meaningful analysis in the sense that theoretically we analyze per capita income so as to compare country growth figures. Divide through (4) by L to obtain :

$$\frac{\dot{K}}{L} = sy_{it} - \delta k_{it} \qquad \textbf{(5)}$$

where $k_{it}$is the capital stock per worker at time t. Accordingly, as shown in appendix part 1.1, per worker physical capital evolution can be expressed as follows using (5) :

$$\frac{\dot{k}_{it}}{k_{it}} = sA_{it}k_{it}^{\alpha-1} - (n + \delta) \qquad \textbf{(6)}$$

Equation (6) expresses the laws of motion for per worker physical capital stock. n is the exogenous growth rate of labor. The term $(n + \delta)$ is the effective depreciation rate for per worker capital and positive.

Similarly, we can write the dynamics of the growth rate of technology as follows:

$$\frac{\dot{A}_{it}}{A_{it}} = Y_{it}^{\beta 1}{FI_{wit}}^{\phi}{A_{it}}^{\theta-1} - \gamma \quad \textbf{(7)}$$

where as stated before 0 < β1<1, Φ < =1 and 0<θ < 1.

1.2.5 The Balanced Growth Equilibrium and Dynamics :

In order to examine balanced growth path[1] (BGP) equilibrium and the behavior of the variables around it, we will solve the system of equations (6) and (7) simultaneously. In this model specification, it is explicitly assumed that the economies are developed and thus close or at their balanced growth path equilibrium. With this assumption, we are able to use Taylor approximation to linearize around the BGP equilibrium even if economies are still in their transitionary phase to the steady state.

The balanced growth path concept is in agreement with stylized empirical facts about growth and demonstrates itself in most of the developed countries where the growth rates of labor, capital, and output are approximately constant.[2] This implies that,

$$\frac{\dot{k}}{k} = \Omega_k \qquad \textbf{(8)}$$

and

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[1] (Acemoğlu, Economic Growth Lectures 2-3 Solow Growth Model, 2011) express that in engineering and physical sciences, equilibrium is a point of rest of a dynamical system; thus the steady state equilibrium. In economics steady state is actually describing a "Growth Path" where capital per capita is growing at a constant rate in stead of static capital per capita without level without any growth. This also implies y and c are also growing at constant rates, thus should not look for "steady states" where y(t) is constant but for "balanced growth paths" where y(t) grows at constant rate.

(Acemoğlu, Introduction to Modern Economic Growth, 2009) also state that balanced growth equilibrium is an allocation where income grows at a constant rate and ratio of capital to output, the interest rate and shares of factors are constant.

[2] (Romer D. , Advanced Macroeconomics, 2012) also summarizes all these stylized facts about growth which was first described by (Kaldor, 1961). What Kaldor noted in his influential paper is the empirical fact that as output per capita increases, the capital to output ratio, the interest rate and the distribution of income between capital and labor are approximately constant.

$$\frac{\dot{A}}{A} = \Omega_A \qquad \textbf{(9)}$$

where Ω_k and Ω_A denote that per worker capital and the technology are constant once we reach balanced growth path equilibrium and also along that path onwards. This implies

$$sA_{it}k_{it}^{\alpha-1} - (n+\delta) = \Omega_k \qquad \textbf{(10)}$$

$$Y_{it}^{\beta 1}{FI_{wit}}^{\phi}{A_{it}}^{\theta-1} - \gamma = \Omega_A \qquad \textbf{(11)}$$

By definition, expressions on left hand-side of (10) and (11) are constant as well. As shown in appendix part 1.2, we may represent these two cases by differentiating equations (10) and (11) with respect to time. We obtain growth rate of the growth rate of per worker capital and *growth rate* of the growth rate of technology, which is zero as follows (or more succintly expressed as second derivatives with respect to time equal zero) (Romer D. , Advanced Macroeconomics, 2012) :

$$\frac{\dot{A_{it}}}{A_{it}} + (\alpha - 1)\frac{\dot{k}_{it}}{k_{it}} = 0 \qquad \textbf{(12)}$$

$$\beta 1\frac{\dot{Y_{it}}}{Y_{it}} + (\theta - 1)\frac{\dot{A}_{it}}{A_{it}} = 0 \qquad \textbf{(13)}$$

As shown in appendix part 1.3 from (12), (13) and some identities we obtain following unique positive values of growth rates of per worker capital and technology that imply *growth rate* of their growth rates $\frac{d}{dt}(\Omega_k), \frac{d}{dt}(\Omega_A)$ is zero:

$$\Omega_k = \frac{\beta 1 n}{(1-\alpha)(1-\theta) - \beta 1} \qquad \textbf{(14)}$$

$$\Omega_A = \frac{(1-\alpha)\beta 1 n}{(1-\alpha)(1-\theta)-\beta 1} \qquad \textbf{(15)}$$

Equations (14), (15) express growth rates of per worker capital and technology level in terms of the system parameters, which are constant. Once A and k reach Ω_A, Ω_k respectively both will grow steadily at these rates and per worker income will grow at $\Omega_A + \Omega_k$, thus economy will be on a balanced growth path.

After (Romer P. , Increasing Returns and Long-run Growth, 1986) AK model, endogenous growth studies focused on models explaining long run growth through technological progress or “scale effects”, which hypothesizes that increase in labor resources devoted to R&D should increase growth rate of economy. (Jones, 1995) defines semi endogenous growth model, where growth in per worker capital is equal to growth rate of A. In all these models, along the balanced growth path, output per worker is proportional to the stock of ideas or innovations.

Balanced growth path equilibrium values of per worker capital and technology can be simultaneously solved with these constant growth rates and using some identities. It can be trivially derived by substituting the right hand side values in equation (14) and (15) into equations (10) and (11) and solving for the levels of A(t) and k(t) which is shown in appendix part 1.4. Denoting derived values by a ‘g’ superscript, representing that these values are valid along the balanced growth path equilibrium :

$$k_t^g = \frac{s^{\frac{[1-(\theta+\beta 1)]}{D}} \cdot L^{\frac{\beta 1}{D}} \cdot FI_w^{\frac{\phi}{D}}}{[\Omega_A+\gamma]^{\frac{1}{D}} \cdot [\Omega_k+(n+\delta)]^{\frac{1-(\theta+\beta 1)}{D}}} \qquad \textbf{(16)}$$

and

$$A_t^g = \frac{s^{\frac{\alpha\beta 1}{D}} \cdot L^{\frac{\beta 1(1-\alpha)}{D}} \cdot FI_W^{\frac{\phi(1-\alpha)}{D}}}{[\Omega_A+\gamma]^{\frac{1-\alpha}{D}} \cdot [\Omega_k+(n+\delta)]^{\frac{\alpha\beta 1}{D}}} \qquad \textbf{(17)}$$

where

$$\mathrm{D} = (1-\alpha)(1-\theta) - \beta 1 \qquad \textbf{(18)}$$

From the expressions in (16) and (17) we see that at the BGP, levels of per worker physical capital stock and the technology depend on the financial innovation characteristics of an economy, level of the labour force and its growth rate, and saving rate along with other constant values coming from the specification of production function.

1.2.6 The Quantitative Measure of the Speed of Convergence:

Transitional dynamics[3] of the system formed by equations (10) and (11) can be quantified by deriving the speed of convergence. The idea is to use log linearisation of the two equations around BGP equilibrium points A_t^g, k_t^g. Therefore, it is effectively being assumed that the eigenvalues of the Jacobian of the system made up of equations (10) and (11) are within the stability range. We start by defining (10) and (11) as functions of log of their inputs :

[3] (Barro & Sala-i Martin, 1992) mention that if convergence coefficient is high, then we can work on balanced growth path dynamics because economies are expected to be close to their balanced growth path. On the contrary, then economies may be far from their BGP equilibrium and growth dynamics would be governed by their transitional dynamics.

$$\frac{\dot{k}}{k} = sA_{it}k_{it}^{\alpha-1} - (n+\delta) \equiv \mathrm{g}_k\ (LnA, Lnk)$$

$$\frac{\dot{A}}{A} = Y_{it}^{\beta 1} FI_{it}{}^{\phi} A_{it}{}^{\theta-1} - \gamma \equiv \mathrm{g}_A\ (LnA, Lnk)$$

Here g_k and g_A denote re-expressing this system of first order nonlinear differential equations as functions of log A and log k. As shown in appendix part 1.5 and also 1.6, the solution for the system aproximated by first order Taylor polynomial around A_t^g, k_t^g gives following functional expression for Ln [k(t)]:

$$\ln k_t = [\ln k(0) - \ln k^g]e^{-\beta t} + \ln k^g \qquad \textbf{(19)}$$

For any $t \geq 0$, the level of per worker capital is a weighted average of the initial and the balanced growth path values with weight on the starting value of capital stock declining exponentially at the rate of $\beta > 0$, which is the speed of convergence.

log [A(t)] can also be written in the same way,

$$\ln A_t = [\ln k(0) - \ln k^g] \frac{-\beta}{(\Omega_k + (n+\delta))} e^{-\beta t} + \ln A^g \qquad \textbf{(20)}$$

and the time path for log[y(t)] is given by

$$\ln y(t) = \left[1 - e^{-\beta t}\right] \ln y^g + e^{-\beta t} \ln y(0) \qquad \textbf{(21)}$$

In order to find the value of β in terms of the system parameters we solve for the eigenvalues of the system formed by (10) and (11) around BGP values which gives us the speed of convergence, β:

$$-2\beta = \left\{ \left[(\alpha-1)[\Omega_k + (n+\delta)] + (\beta 1 + \theta - 1)[\Omega_A + \gamma]\right] - \left(\left[(\alpha-1)[\Omega_k + (n+\delta)] + (\beta 1 + \theta - 1)[\Omega_A + \gamma]\right]^2 + 4\{\alpha\beta 1[\Omega_A + \gamma] \cdot [\Omega_k + (n+\delta)]\}\right)^{\frac{1}{2}} \right\} \quad \textbf{(22)}$$

The parameter β is measured by how much growth rate declines as the capital stock increases in proportion. [4] Technically as per equation (21), convergence coefficient is the measure of how fast the per worker production converges to its balanced growth path values. The higher β, the sooner will difference between log [y(0)] and log $[y(t)^g]$ will tend to zero and thus per worker growth $\ln y(t)$ will be equal to $\ln y^g$, and vice versa if opposite conditions hold. As shown in appendix part 1.5 and also 1.6, it is straightforward to show that the two eigenvalues of this system have opposite signs implying saddle-path stability. Taking into consideration this result, the arbitrary constant on positive eigenvalue must equal zero so that the system becomes stable and converge. Therefore negative eigenvalue of the system solution is used to specify the per worker income $\ln y(t)$ around balanced growth path values A_t^g, k_t^g .

[4] Here we adopt (Barro & Sala-i Martin, 2004) definition of β : The *speed of convergence*, β, is measured by how much the growth rate declines as the capital stock increases in a proportional sense, that is, $\beta \equiv -\partial(\dot{\hat{k}}/\hat{k})/\partial \log \hat{k}$(1.42). Notice that we define β with a negative sign because the derivative is negative, so that β is positive.

1.3. Model Specification at Balanced Growth Path for Empirical Analysis

In order to empirically test the model we need to derive expression for per worker income $y(t)^g$ around BGP values. As shown in appendix part 1.7, we do so by substituting equations (16) and (17) into the model

$$y(t)^g = A(t)^g[k(t)^g]^\alpha \qquad \textbf{(23)}$$

Further substitute expressions in (16) and (17) into (23) to obtain per worker income as a function of system variables and constants :

$$y(t)^g = \left[\frac{s^{\alpha(1-\theta)}}{\Omega_A+\gamma}\,\frac{L^{\beta 1}\cdot FI^{\phi}}{[\Omega_k+(n+\delta)]^{\alpha(1-\theta)}}\right]^{1/D} \qquad \textbf{(24)}$$

where $\mathrm{D} = (1-\alpha)(1-\theta)-\beta 1$

Here we see that per worker income y around the BGP is proportional to the level of financial innovation and the level of Labor force and saving rate. The more Labor Force interacts with financial innovations, their efficiency will increase and thus the higher per worker income will be. Similarly, the higher the efficiency of Labor from interacting with financial innovation, will increase the positive effect of savings on per worker income around BGP values.

Taking the natural logarithm of (24) and inserting into the equation (21) gives us the empirical specification to be tested with data :

$$\ln y_{it} = \{(1 - e^{-\beta t})\alpha(1-\theta)\ln s_{it} + (1 - e^{-\beta t})\beta 1 \ln L_{it} + (1 - e^{-\beta t})\phi \ln FI_{it} + (1 - e^{-\beta t})\ln[\gamma + (1-\alpha)\beta 1 n_{it}] + (1 - e^{-\beta t})\alpha(1-\theta)\ln[(n_{it}+\delta) + \beta 1 n_{it}]\} + e^{-\beta t}\ln y_{it-1} + u_{it} \quad \textbf{(25)}$$

The first coefficient is positive $(1 - e^{-\beta t})\alpha(1-\theta) > 0$ and clearly implies that as the saving rate increases, the more a country's per worker income grows. The second coefficient $(1 - e^{-\beta t})\beta 1$ is positive, indicating that the size of the labour force is a positive factor on per worker income. The third coefficient $(1 - e^{-\beta t})\phi$ shows the effect of the financial innovation on the production of a country and it is expected to be positive. For a given α, $\beta 1$, γ, δ and θ, per worker income is positively related to the exponential growth of labour force. Finally, the last term $e^{-\beta t}$ indicates that if per worker income is below BGP level, economy will grow faster so as to converge to BGP level.

1.4. Data Description

GDP per capita (y), Labor force (L), Saving Rate (s), Banking sector loans and provision on loans data for 11 OECD member countries through years 1991 – 2009 have been compiled from OECD, Worldbank and Penn World Tables, version 9.0 (Feenstra, Inklaar, & Timmer, 2015).

From banking sector loans and provision on loans raw data, Financial Innovation data has been calculated manually. Also growth in Labor Force (n) has been manually calculated from Labor Force data. Then average growth rate per each country for the years 1992 – 2009 is manually calculated and used. The model dependent variable is

GDP per worker and we proxy it by using GDP per capita since it is directly available from World Bank database. Depreciation rate of capital (delta) and depreciation rate of technological advances (gamma) has been taken constant values of 0,06 and 0,12. The underlying idea is that technological advances will become obsolete much faster compared to capital stock. Since saving rate (s) and growth in labor force (n) are percentages, they have been scaled by multiplying with 100.

Details of data definitions and sources are provided via Table 15 at Appendix. Table 1 provides descriptive statistics for dependent and independent variables in the model.

Table 1 Descriptive Statistics for FI Variable Model Table

	y	L	s	FI	n
Mean	24656.79	16076781	25.29	0.011	0.96
Median	22109.60	17345152	24.76	0.008	1.08
Max	96880.51	41935810	41.23	0.22	2.19
Min	2192.67	2143460	11.43	0.00	0.01
Std. Dev.	18039.48	11155482	5.76	0.017	0.75
Observations	209	209	209	209	209

Note : GDP per capita and labor force is measured in original levels, saving rate is percentage, financial innovation is proportion of provision on loans to total loans and labor force growth is in percentages.

Correlation matrix for regressors are provided via Table 2.

Table 2 Cross Corelation of Variables

	FI	L	n	s
FI	1	-0.005	-0.023	-0.16
L		1	-0.199	0.014
n			1	0.245
s				1

Note : From the matrix there exist weak negative corelation between labor force growth and total labor force levels and also between financial innovation and saving rate. There is weak positive corelation between saving and labor force growth. In the overall no perfect or high negative or positive corelation between regressors is noted.

1.5. Methodology and Results

Panel data through exploiting both time series and cross-section characteristics presents the researcher with much higher number of data observations compared to pure cross-sectional or time series data sets.

Since model derived and specified in (25) is nonlinear, we have to resort to nonlinear estimation techniques for empirical part of this study.

Regression model is called "nonlinear", if derivative of the model with respect to parameters depends on one or more parameters. When we have a specification which cannot be reduced to linear form in spite of all manipulations, then take recourse to Non Linear Regression (NLR). The main steps in NLR are : i) assume starting point for unknown coefficient vector. ii) expand nonlinear regression function around the assumed starting values using Taylor expansion. Truncate Taylor series after a certain number of terms (i.e. approximation with first order terms). iii) Define stopping criteria for difference between successive coefficient values in order for iteration to stop. As is the case with any iterative technique, successful solution is critically dependent on initial values of coefficient vector. The number of iterations is considerably reduced if the initial starting values denoted by $\widehat{\theta_0}$ are close to optimum estimate $\hat{\theta}$. A poor choice of starting values can lead to failure of iterative methods. If the objective function is not globally concave it is good practice to use a range of starting values to increase the chance of obtaining a global minimum / maximum. Based on this, algorithm may converge slowly, oscillate or diverge[5]. In order to overcome these difficulties one may resort to a strategy of beginning iterations at a wide range of starting values or to perform a grid search. Both of these approaches theoretically require evaluations at many different points if the dimension of $\hat{\theta}$ is large and then use finer grids. Considering the panel data set and non-linear nature of the endogenous model specification, iterative optimization technique namely, Panel Nonlinear Least Squares Method with Gauss-Newton Algorithm (GNA) has been used via Eviews® 9 econometric software.

1.5.1. Non Linear Least Squares with Gauss Newton Algorithm (GNA)

In this section steps regarding numerical optimization using GNA is derived explicitly so as to make the method more concrete. Given data (y_i, x_i) and $\theta_i = \begin{pmatrix} \theta_1 \\ \vdots \\ \theta_N \end{pmatrix}$ is the vector of coefficients to be estimated and e_i is random error terms;

$y_i = f(x_i, \theta_i) + e_i$ where $i = 1\ to\ N$

Expand model with given data points using first order Taylor Series around selected starting points θ_i^*, where i is coefficient vector component number, j is iteration number, superscript "*" is to highlight these are specific starting points rather than placeholder for vector components. Note that higher order Taylor approximation terms are truncated;

[5] (Balaji, 2011) provides details.

$$f(x_i, \theta_i^*)_{j+1} = f(x_i, \theta_i^*)_j + \frac{\partial f(x_i, \theta_i^*)}{\partial \theta_1}(\theta_1 - \theta_1^*) + \frac{\partial f(x_i, \theta_i^*)}{\partial \theta_2}(\theta_2 - \theta_2^*) + \cdots + \frac{\partial f(x_i, \theta_i^*)}{\partial \theta_N}(\theta_N - \theta_N^*)$$

Substitute Taylor expansion of $f(x_i, \theta_i^*)$ into first equation to get third equation below

$$y_i = f(x_i, \theta_i^*)_j + \frac{\partial f(x_i, \theta_i^*)}{\partial \theta_1}(\theta_1 - \theta_1^*) + \frac{\partial f(x_i, \theta_i^*)}{\partial \theta_2}(\theta_2 - \theta_2^*) + \cdots + \frac{\partial f(x_i, \theta_i^*)}{\partial \theta_N}(\theta_N - \theta_N^*) + e_i$$

Third equation in expanded form is below :

$$y_1 = f(x_1, \theta_i^*)_j + \frac{\partial f(x_1, \theta_i^*)}{\partial \theta_1}(\theta_1 - \theta_1^*) + \frac{\partial f(x_1, \theta_i^*)}{\partial \theta_2}(\theta_2 - \theta_2^*) + \cdots + \frac{\partial f(x_1, \theta_i^*)}{\partial \theta_N}(\theta_N - \theta_N^*) + e_1$$

$$y_2 = f(x_2, \theta_i^*)_j + \frac{\partial f(x_2, \theta_i^*)}{\partial \theta_1}(\theta_1 - \theta_1^*) + \frac{\partial f(x_2, \theta_i^*)}{\partial \theta_2}(\theta_2 - \theta_2^*) + \cdots + \frac{\partial f(x_2, \theta_i^*)}{\partial \theta_N}(\theta_N - \theta_N^*) + e_2$$

$$\vdots$$

$$y_N = f(x_N, \theta_i^*)_j + \frac{\partial f(x_N, \theta_i^*)}{\partial \theta_1}(\theta_1 - \theta_1^*) + \frac{\partial f(x_N, \theta_i^*)}{\partial \theta_2}(\theta_2 - \theta_2^*) + \cdots + \frac{\partial f(x_N, \theta_i^*)}{\partial \theta_N}(\theta_N - \theta_N^*) + e_N$$

Move first terms to LHS and express all in vector – matrix notation via fourth equation below :

$$\left(y_i - f(x_i, \theta_i^*)_j\right) = \begin{bmatrix} \frac{\partial f(x_1,\theta_i^*)}{\partial \theta_1} & \frac{\partial f(x_1,\theta_i^*)}{\partial \theta_2} & \cdots & \frac{\partial f(x_1,\theta_i^*)}{\partial \theta_N} \\ \frac{\partial f(x_2,\theta_i^*)}{\partial \theta_1} & \frac{\partial f(x_2,\theta_i^*)}{\partial \theta_2} & \cdots & \frac{\partial f(x_2,\theta_i^*)}{\partial \theta_N} \\ \vdots & \vdots & & \vdots \\ \frac{\partial f(x_N,\theta_i^*)}{\partial \theta_1} & \frac{\partial f(x_N,\theta_i^*)}{\partial \theta_2} & \cdots & \frac{\partial f(x_N,\theta_i^*)}{\partial \theta_N} \end{bmatrix} \begin{pmatrix} \Delta\theta_1 \\ \Delta\theta_2 \\ \vdots \\ \Delta\theta_N \end{pmatrix} + \begin{pmatrix} e_1 \\ e_2 \\ \vdots \\ e_N \end{pmatrix}$$

Notice LHS term is a vector, Matrix on RHS is Jacobian Matrix (~sensitivity matrix), remaining terms are vectors.

Expressing fourth expression more compactly let;

$\left(y_i - f(x_i, \theta_i^*)_j\right) = \{D\}$ which is Forcing Vector

$$\begin{bmatrix} \frac{\partial f(x_1,\theta_i^*)}{\partial \theta_1} & \frac{\partial f(x_1,\theta_i^*)}{\partial \theta_2} & \cdots & \frac{\partial f(x_1,\theta_i^*)}{\partial \theta_N} \\ \frac{\partial f(x_2,\theta_i^*)}{\partial \theta_1} & \frac{\partial f(x_2,\theta_i^*)}{\partial \theta_2} & \cdots & \frac{\partial f(x_2,\theta_i^*)}{\partial \theta_N} \\ \vdots & \vdots & & \vdots \\ \frac{\partial f(x_N,\theta_i^*)}{\partial \theta_1} & \frac{\partial f(x_N,\theta_i^*)}{\partial \theta_2} & \cdots & \frac{\partial f(x_N,\theta_i^*)}{\partial \theta_N} \end{bmatrix} = [Z_j]$$ [6] which is Jacobian Matrix

$$\begin{pmatrix} \Delta\theta_1 \\ \Delta\theta_2 \\ \vdots \\ \Delta\theta_N \end{pmatrix} = \{\Delta\theta\}, \begin{pmatrix} e_1 \\ e_2 \\ \vdots \\ e_N \end{pmatrix} = \{E\}$$

Now, in order to minimize $\{E\}$, the idea is to find $\{\Delta\theta\}$ with iteration through conducting artificial regression.[7]

$\{D\} = [Z_j]\{\Delta\theta\}$

$[Z_j]^T\{D\} = [Z_j]^T[Z_j]\{\Delta\theta\}$

Start with $\{\theta_i^*\}$ and get $\{\Delta\theta_i\}$ then use $\theta_{ij+1} = \theta_{ij} + \Delta\theta_{ij}$ to reiterate.

Define stopping criteria :

$|\theta_{ij+1} - \theta_{ij}| * 100 \leq \varepsilon_i$

---

[6] We call it Z_j because matrix values are not constant in the iterative procedure, like it was in Linear Least Squares.

[7] (Cameron & Trivedi, 2005) and (Balaji, 2011) provides details

1.5.2. Results of Data Analysis

As stated earlier, convergence of the nonlinear iterative technique critically depends on starting values of coefficient vector. Therefore panel nonlinear least squares has been simulated for various starting values of coefficient vector which are implied by theory using different step sizes. As a by-product of this simulation study for different starting values implied by macroeconomic theory, Sum of Squared Residual (SSR) values for the converged parameter values were compared. This exercise enabled to determine any converged coefficient values for which SSR objective function is at a local minima rather than a global one for the simulated starting values.

Values of the coefficient vector has been simulated for starting values and step sizes provided in Table 3 below :

Table 3 Simulation starting values for the coefficient vector in nonlinear least squares estimation

Simulation inputs	Starting Values				
	$(1 - e^{-\beta t})$	k^{α}	A^{θ}	FI^{ϕ}	$Y^{\beta 1}$
	β	**α**	**θ**	**ϕ**	**β1**
Range	0.01 to 0.09	0.1 to 1	0.1 to 0.9	-0.1 to 0	0.1 to 0.4
Step size	0.05	0.1	0.1	0.5	0.1

Note : constant returns to scale in production function implies range of values displayed in table for capital share in GDP denoted by α. Range of values for θ, β1 and ϕ reflect the fact that we allow returns to technology may be increasing or decreasing to scale. Moreover proxy variable for financial innovation is constructed to vary negatively with growth, and thus range of values for ϕ are between negative values and zero.

Convergence coefficient simulation range of values reflect the view that developed countries are assumed to be close to steady state growth phase.

As a result of total 2.160 nonlinear least squares simulations 470 has converged having the same SSR and coefficient values whereby results are thus provided via Table 4 below:

Table 4 Results of nonlinear least squares estimation of GDP per capita on balanced growth path determinants of endogenous growth model

Parameters	Estimates	t-Statistic
β	0.002866***	3.53
α	1.049627***	12.45
ϕ	-0.981314***	-4.26
β1	0.506454***	7.44
θ	0.821053***	2.45
R^2	0.986	
SSR	2.24671	

Notes : * is significant at 10%, ** is significant at 5%, *** is significant at 1%.

Results of the non-linear estimation of dynamic econometric specification (25) are evaluated as follows. Coefficient of saving rate is positive as theory implies and also statistically significant. Therefore the more a country saves has positive effect on per capita GDP growth. Moreover θ denoting returns to technology from existing technology stock is also statistically significant and near one to one correspondence with per worker GDP. One percent increase in current technology level would increase

GDP by 0.82 percent. The level of Labor Force level has positive and statistically significant effects on GDP. One percent increase in employment rate would increase per capita GDP 0,50 percent on average. The income share of physical capital α estimate is unity where a one percent increase in capital per worker would increase per worker output by 1,05 percent. This result can be explained by market power of banking sector in the sample of countries. Theoretically as per (Romer P. , Endogeneous Technological Change, 1990) where model incorporates market power through imperfect competition, partial excludability implies that firms have market power and can earn positive rents. In a recent article (Romer P. , Mathiness in the Theory of Economic Growth, 2015) states that his initial studies on economic growth incorporated price taking and external increasing returns, but then reverted to monopolistic competition in the sense that it allowed ideas to be partially excludable.

Financial innovation proxy **FI variable** has statistically significant and even stronger impact on per capita GDP, but negatively, which was in line with expectations since this implies that there is positive relationship between concept of financial innovation and growth. The proxy variable for financial innovation was degined to increase (decrease) in levels when innovation is low (high). One percent increase/decrease in FI would decrease/increase per capita GDP, 0,98 percent on average. This result resembles (Borucu & Ulusoy, 2012) who find that sector-based non-performing loans are negatively related to real sector growth.

There is still ongoing theoretical debate on whether financial innovation has positive or detrimental effect on growth and both views are supported by empirical studies, this result falls within theoretical expectations. Especially the most recent financial crisis of

2007-2008 is perceived by many to be triggered by financially innovating derivative products which were inherently risky but marketed to be riskless. As mentioned in section 1.1 see for example (Gennaioli, Shleifer, & Vishny, 2011), also (Chava, Oettl, Subramanian, & Subramanian, 2013) and more recently (Beck, Chen, Lin, & Song, 2016) find evidence supporting both bright and dark sides of financial innovation. And we also find evidence supporting bright side as well.

Convergence coefficient β is statistically significant and quite low which may imply that as our sample consists of OECD member economies, GDP growth of these economies is slow and will be effective in the long run. This may be due to the fact that our sample OECD countries include both developed and also emerging economies.

Since α coefficient is estimated at upper bound of theoretical value and converged for β1 values = $\{0.2, 0.3, 0.4\}$ I also performed a finer grid search using a smaller step size of 0.01 around these values. The objective was to check whether α converges to a lower value (i.e. theoretical value $0<\alpha<1$) and at the same time whether lower SSR is achieved for these starting values. As a result 10,800 additional nonlinear least squares simulations via Gauss Newton Algorithm (GNA) has been performed and 2603 of them converged. All converged coefficients and SSR values are the same as per original simulation so we end simulation study.

1.6. CONCLUSION

This study aims to investigate relation between financial innovation and macro economic growth within an endogenous growth model. It has several contributions to literature, few empirical studies have been conducted on this highly debated subject matter due to lack of proxy variable data representing financial innovation. In this study a genuine proxy variable for financial innovation has been defined. Moreover past empirical studies used linear or log-linear specifications whilst a nonlinear specification has been used in this study where concept of convergence coefficient has been explicitly derived within the model as well. Other studies on financial innovation used nonlinear estimation such as GMM but an iterative non linear estimation technique has been applied in this study also heavily utilizing results of simulations conducted. Needless to mention that the important concept within Endogenous Growth theory namely Balanced Growth Path (BGP) Equilibrium and stability analysis of this equilibrium has also been derived explicitly for the case of this study. Nonlinear estimation of coefficient on financial innovation proxy variable shows near one to one effect on per worker income negatively. The negative sign on coefficient was no surprise since by construct, we designed proxy variable for financial innovation to increase(decrease) in levels when innovation is low(high) and per worker income decreases(increases). Therefore conclusion is that financial innovation in the form of credit early warning systems has near one to one positive relationship with per worker growth. This study leaves further research on nonlinear estimation of specified model and variables using different iterative algorithms other than Gauss Newton Algorithm (GNA) and also whether alternative financial innovation proxies can be developed like the one used here, compared to widely used R&D expenditures of financial sector.

CHAPTER 2 EFFECTS OF HUMAN CAPITAL ON ENDOGENOUS GROWTH

ABSTRACT

The aim of this chapter is to build on endogenous growth model derived in chapter 1 and replace financial innovation variable FI with human capital variable HC so as to test empirically relation between Human Capital and Growth with a panel non-linear least squares method, to determine whether coefficient estimates converge or not and if so compare and contrast results with FI variable results. According to simulation results conducted with theoretically implied values of coefficients as starting points, coefficients did not converge as a result of iterations.

Keywords : Human Capital, Endogenous Growth Model, Convergence, Balanced Growth Path, Panel Nonlinear Least Squares, Gauss Newton Algorithm (GNA), simulation

2.1 Introduction and Literature Review

The aim of this chapter is to build on endogenous growth model derived in chapter 1 and replace financial innovation variable FI with human capital variable HC so as to test empirically relation between Human Capital and Growth with a panel non-linear least squares method, to determine whether coefficient estimates converge or not and if so compare and contrast results with FI variable results.

In his seminal book on the subject human capital, (Becker, Human Capital, 1694) argues that employers will not be willing to invest in general training when labor markets are competitive. In this respect general human capital is generic knowledge and skill not specific to a task or a company, obtained through working experiences and education. The general human capital holds 'transferable' characteristic across jobs, firms and industry. However, they are willing to invest in specific training because it cannot be transferred to outside firms. Therefore, human capital is "specific" if it increases a worker's productivity only at the firm.

(Becker, The Economic Way of Looking at Life, 1992) also when delivering his Nobel Lecture for receiving the award for economic sciences, has made a very clear definiton of the research on human capital as follows "the human capital perspective considers how the productivity of people in market and nonmarket situations is changed by investments in education, skills, and knowledge."

(Mincer, 1974) on his seminal study of the effect of labor market experience or on the-job training on the determination and distribution of earnings. The earnings function approach pioneered by the author, estimates an earnings function based on data on the earnings of large samples of individual workers along with their investments in education and training. Estimates of rates of return on years of schooling or on individual qualifications can be obtained from such an analysis.

In the seminal paper on endogenous growth theory (Romer P. , Increasing Returns and Long-run Growth, 1986), investment in human capital is underlined as an significant factor contributing to growth.

(Lucas, Jr, 1988) develops endogenous theoretical model which postulates human capital accumulation through schooling and also a model where specialized human capital accumulation is done via learning-by-doing.

(Barro R. , Economic growth in a cross-section of countries., 1991) conducted regression for real growth rate of GDP per capita to initial human capital for which school enrolment rates for the year 1960 is used as proxy, and also large set of other regressors related to growth. Data covering 98 countries from 1960 to 1985 has been used. He concluded that output growth was significantly positively determined by both primary and secondary school enrolment, in the presence of other determinants.

In their seminal paper (Mankiw, Romer, & Weil, 1992) derive augmented Solow model to explain cross country differences in income levels and test empirically how income per capita depends on population growth and accumulation of physical and human capital. Human capital, as proxied by secondary school enrolment ratios, accounts for almost half the difference in per capita incomesThey argue that much of cross country differences in income per capita has roots in different accumulation of physical and human capital and population growth.

(Glomm & Ravikumar, 1992) examine the implications of public investment in human capital on growth and the evolution of income inequality in an economy where labor force has different income/skills within a endogenous growth model. In their model time allocated to schooling is decided privately and define schooling as basic engine of growth. In their theoretical study they define two regimes of education public schools where decision to invest in quality of schools is made by majority votes, and private schools where household chooses quality. They conclude that public education reduces income inequality more quickly than private education.

(Benhabib & Spiegel, 1994) use a log first differenced linear model for per capita growth rates and conducts OLS regression new set of country comparative data where growth rate of human capital stock is used as a factor of production function, yields insignificant and generally negative coefficients. They modify the specification by including average stock of human capital in a period compared to growth rate and results are positive and significant.

(Sjögren, 1998) studies interaction between human capital and R&D through endogenous human capital accumulation in an economy that expands variety of products and technologies through R&D done by profit maximizing entrepreneurs. She concludes determinant of that long run growth is capacity of economy to accumulate human capital.

(Boucekkine, de la Croix , & Licandro, 2002) develop a model to study how economic growth is affected by demographics where individuals choose leaving date from school and entering date to labor market via optimal decisions. They find that endogenous growth prevails due to generation specific accumulation of human capital.

(Acemoğlu, Gallego, & Robinson, Institutions, Human Capital and Development, 2014) argue that empirical models where institutions and human capital variables are exogenous are misspecified because of omitted variable bias and of measurement error in these variables. They assert that this misspecification has erronously caused these studies to find very large returns of human capital, about 4 to 5 times greater than that implied by Mincer Equation estimates. They use cross-country and cross-regional regressions applying OLS and 2SLS methodology to assess the roles of human capital and institutions in long-run economic development. Cross-country regression of log of

GDP, years of schooling of the population above 15 years of age in 2005 as proxy for Human Capital and rule of law index for 2005 from the Worldwide Governance Indicators constructed by the WorldBank as proxy for institutions along with control variables is conducted. Because human capital is correlated with institutions because instittutions also shape human capital, the effect of institutions will be reflected on coefficient estimate of human capital. They conclude that estimation controlling for historical determinants of institutions directly and instrumenting for average years of schooling with its historical determinants signicantly reduces the estimates of the effect of human capital on GDP per capita today and brings these estimates in line with the Mincer equation estimates.

2.2 The Derivation of Model Sprecification at Balanced Growth Path for Empirical Analysis

In order to be able to compare and contrast effects of Human Capital and Financial Innovation variables, we build on the endogenous growth model and specify the same regression with the exception that Financial Innovation variable is replaced by Human Capital variable HC as follows

$$\ln y_{it} = \{(1 - e^{-\beta t})\alpha(1-\theta)\ln s_{it} + (1 - e^{-\beta t})\beta 1 \ln L_{it} + (1 - e^{-\beta t})\phi \ln HC_{it} + (1 - e^{-\beta t})\ln[\gamma + (1-\alpha)\beta 1 n_{it}] + (1 - e^{-\beta t})\alpha(1-\theta)\ln[(n_{it} + \delta) + \beta 1 n_{it}]\} + e^{-\beta t}\ln y_{it-1} + u_{it} \qquad \textbf{(26)}$$

2.3 Data Description

Real GDP (y), Employment (L), Saving Rate (s), Human Capital (hc) data for 24 OECD member countries through the years 1978 – 2014 has been obtained from Penn World Tables, version 9.0 (Feenstra, Inklaar, & Timmer, 2015). Human Capital (hc) variable is an index number based on averager years of schooling and assumed rate of return to education based on Mincer Equation[8] estimates around the world. GDP per worker is manually calculated by dividing real GDP by employment variable. Depreciation rate of capital (delta) and depreciation rate of technological advances (gamma) has been taken constant values of 0,06 and 0,12. The underlying idea is that technological advances will become obsolete much faster compared to capital stock. Since saving rate (s) and growth in labor force (n) are percentages, they have been scaled by multiplying with 100. Since saving rate (s) and growth in labor force (n) are percentages, they have been scaled by multiplying with 100.

Details of data definitions and sources are provided via Table 15 at Appendix. Table 5 provides descriptive statistics for dependent and independent variables in the model.

Table 5 Descriptive statistics for HC variable model data:

	y	L	s	HC	n
Mean	66341.41	18.25	25.74	2.96	1.14
Median	64087.88	6.04	25.52	3.04	0.91
Max	160501.1	148.46	56.38	3.73	2.99
Min	23713.55	0.11	8.85	1.42	0.33
Std. Dev.	22706.12	27.74	4.83	0.48	0.83
Observations	888	888	888	888	888

[8] The Mincer earnings function invented by Jacob Mincer provides functional relationship between wage and schooling and experience, in a single equation model setting.

Note : GDP per capita is measured in levels, labor force is measured in millions of workers, saving rate is percentage, human capital is an index number and labor force growth is in percentages.

Correlation matrix for regressors are provided via Table 6.

Table 6 Cross Corelation of Variables

	L	n	s	HC
L	1	-0.07	-0.078	-0.26
n		1	-0.024	-0.012
s			1	0.01
HC				1

Note : From the matrix there exist weak negative corelation between labor force and human capital index. In the overall no perfect or high negative or positive corelation between regressors is noted.

2.4 Methodology and Results

Panel data through exploiting both time series and cross-section characteristics presents the researcher with much higher number of data observations compared to pure cross-sectional or time series data sets.

Since model derived and specified in (26) is nonlinear, we have to resort to nonlinear estimation techniques for empirical part of this study.

Considering the panel data set and non-linear nature of the endogenous model specification, iterative optimization technique namely, Panel Nonlinear Least Squares Method with Gauss-Newton Algorithm (GNA) has been used via Eviews9 econometric software.

2.4.1 Results of Data Analysis

As stated earlier, convergence of the nonlinear iterative technique critically depends on starting values of coefficient vector. Therefore panel nonlinear least squares has been simulated for various starting values of coefficient vector which are implied by theory using different step sizes. As a by-product of this simulation study for different starting values implied by macroeconomic theory, Sum of Squared Residual (SSR) values for the converged parameter values were compared. This exercise enabled to determine any converged coefficient values for which SSR objective function is at a local minima rather than a global one for the simulated starting values. Values of the coefficient vector has been simulated for starting values and step sizes provided in Table 7 below :

Table 7 Simulation values for the coefficient vector in nonlinear least squares estimation

Simulation inputs	Starting Values				
	$(1-e^{-\beta t})$	k^{α}	A^{θ}	HC^{ϕ}	$Y^{\beta 1}$
	β	**α**	**θ**	$\boldsymbol{\phi}$	**β1**
Range	0.01 to 0.09	0.1 to 1	0.1 to 0.9	-0.1 to 0	0.1 to 0.4
Step size	0.05	0.1	0.1	0.5	0.1

Note : Constant returns to scale in production function implies range of values displayed in table for capital share in GDP denoted by α. Range of values for θ, β1 and ϕ reflect the fact that we allow returns to technology may be increasing or decreasing to scale. Convergence coefficient simulation range of values reflect the view that developed countries are assumed to be at steady state growth phase.

As a result of total 3.600 nonlinear least squares simulations no convergence has been achieved for the above starting values. Another interaction variable was defined as

(HC/L) with the idea to capture effects of human capital stock as a ratio to overall labor force. The simulation results same starting values and step sizes given in Table 4 failed to converge.

As stated earlier, convergence of the nonlinear iterative technique critically depends on starting values of coefficient vector. Given this outcome simulation was conducted again for a broader range of starting values, for share of per worker capital α and also ϕ which is share of Human Capital in technological change.

Values of the coefficient vector has been simulated for starting values and step sizes provided in Table 8 below :

Table 8 Second simulation starting values for the coefficient vector in nonlinear least squares estimation

Simulation inputs	Starting Values				
	$(1-e^{-\beta t})$	k^{α}	A^{θ}	HC^{ϕ}	$Y^{\beta 1}$
	β	**α**	**θ**	***ϕ***	**β1**
Range	0.01 to 0.09	1 to 2.9	0.1 to 0.9	-1 to 3	0.1 to 0.4
Step size	0.05	0.1	0.1	0.5	0.1

Note : Range of values for Convergence coefficient β, scale effects of existing technology level and GDP on technological change denoted by θ and β1 are the same as previous simulation. We extend range of values for α and ϕ.

As a result of total 75.090 nonlinear least squares simulations 8.013 has converged having 11 unique SSR values, results are thus provided via Table 9 below:

Table 9 Second simulation converged results in nonlinear least squares estimation (1)

Simulation Number	Coefficients	Converged Coefficient Values	Sum of Squared Residuals (SSR)	Standard Error	t-statistics
1	β	0.0139***		0.0023	6.0347
	α	645.4306***		229.3490	2.8142
	θ	0.9996***	0.0353	0.0002	4936.996
	β1	-0.0658***		0.0076	-8.6262
	ϕ	2.0196***		0.0822	24.5697
2	β	0.0012***		0.0003	4.3644
	α	2.61***		0.8204	3.1816
	θ	0.3405	0.0763	0.2593	1.3133
	β1	0.1973*		0.1059	1.8632
	ϕ	-0.8962		0.9845	-0.9103
3	β	0.0017***		0.0003	5.3529
	α	-5.3615		16.5483	-0.3240
	θ	1.2313*	0.091	0.7005	1.7579
	β1	-0.0178		0.0355	-0.5022
	ϕ	0.7540*		0.4343	1.7363
4	β	0.0016***		0.0003	5.9656
	α	9.3654		17.0413	0.5496
	θ	0.8686***	0.1353	0.2396	3.6251
	β1	0.0152		0.0316	0.4812
	ϕ	0.7542***		0.3173	2.3769
5	β	0.0016***		0.0002	6.5864
	α	8.6564		14.3948	0.6014
	θ	0.8590***	0.1464	0.2346	3.6621
	β1	0.0156		0.0297	0.5246
	ϕ	0.7711***		0.2427	3.1769
6	β	0.0017***		0.0002	7.0323
	α	5.9490		5.0634	1.1749
	θ	0.7936***	0.1567	0.1757	4.5178
	β1	0.0256		0.0261	0.9801
	ϕ	0.7251***		0.2321	3.1239
7	β	0.0015***		0.0002	6.6731
	α	5.2072		4.0468	1.2867
	θ	0.7601***	0.1678	0.1862	4.0821
	β1	0.0294		0.0284	1.0338
	ϕ	0.5903***		0.2516	2.3464
8	β	0.0006***		0.0001	3.8646
	α	4.8967		13.300	0.3682
	θ	0.7031	0.2675	0.8107	0.8673
	β1	0.0164		0.0552	0.2964
	ϕ	-0.5764		0.8381	-0.6878
9	β	0.0006***		0.0001	4.0580
	α	2.2359*	0.3628	1.1794	1.8957
	θ	0.3168		0.3693	0.8577
	β1	0.0501		0.0479	1.0449

Simulation Number	Coefficients	Converged Coefficient Values	Sum of Squared Residuals (SSR)	Standard Error	t-statistics
	ϕ	-1.1855		0.8007	-1.4806
10	β	0.0005***		0.0001	3.8854
	α	2.1392*		1.2096	1.7685
	θ	0.3088	0.3779	0.3972	0.7775
	β1	0.0485		0.0515	0.9423
	ϕ	-0.9006		0.7823	-1.1513
11	β	0.0003***		0.0001	2.8554
	α	1.7752		1.3843	1.2824
	θ	0.0278	0.4688	0.7924	0.0351
	β1	0.0513		0.0917	0.5595
	ϕ	-2.1775		1.6281	-1.3374

(1) Results are sorted according to SSR values in ascending order.

Notes : * is significant at 10%, ** is significant at 5%, *** is significant at 1%.

It is clear that we don't see the same picture as in Financial Innovation variable simulations given in Table 3, where all simulation results had the same SSR and coefficient values. Here we see that only Convergence coefficient, β estimates are coherently close to one another and SSR values increase for different results. All the other coefficient estimates vary, in some cases change sign and are not statistically significant for majority of estimates. So the results are inconclusive, and not within range of values due to theoretical expectations apart from β . This may be due to existence of multiple local optima whereby the GNA algorithm converges to either one of the local optimum points for different starting values.

2.5 CONCLUSION

This study aims to investigate relation between human capital and per worker income within an endogenous growth model. The ultimate aim to compare and contrast results with those in Chapter 1 where interaction of financial innovation and per worker income was examined. Contributions to literature are using a pure nonlinear specification and also deriving concept of convergence coefficient within the model. Other studies on financial innovation used nonlinear estimation such as GMM but an iterative non linear estimation technique has been applied in this study also heavily utilizing results of simulations conducted. Nonlinear estimation of coefficient on human capital variable failed to converge for simulations conducted with different range of starting values implied by theory. Moreover a broader simulation was conducted which returned inconclusive results in the sense that coefficient estimates vary, in some cases change sign and are not statistically significant for majority of estimates. This study stimulates further research on nonlinear estimation of specified model and variables using different iterative algorithms other than Gauss Newton Algorithm (GNA) and also studies on whether Human Capital which is generally accepted to have positive relation with growth, interacts positively only within a pure linear and/or log-linearized model setting and not pure nonlinear model specification.

CHAPTER 3 EFFECTS OF FOREIGN DIRECT INVESTMENT ON ENDOGENOUS GROWTH

ABSTRACT

The aim of this chapter is to build on endogenous growth model derived in chapter 1 and replace financial innovation variable FI with Foreign Direct Investment variable FDI so as to test empirically relation between Foreign Direct Investment and Growth with a panel non-linear least squares method, to determine whether coefficient estimates converge or not and if so compare and contrast results with FI variable results. According to simulation results conducted with theoretically implied values of coefficients as starting points, coefficients did not converge as a result of iterations.

Keywords : Foreign Direct Investment, Endogenous Growth Model, Convergence, Balanced Growth Path, Panel Nonlinear Least Squares, Gauss Newton Algorithm (GNA), simulation

3.1 Introduction and Literature Review

The effect of Foreign Direct Investment on growth and the channels through which it interacts has received considerable attention in literature. From endogenous growth theory perspective FDI is generally considered to stimulate growth through technology transfers and spillovers rather than to promote economic growth of Less Developed Country via supplementing the savings deficit. In other words FDI receiving firms will be positively affected through building human capital by investing in them through knowhow transfer in parallel to receving technology transfer.

(Blomstrom, Lipsey, & Zejan, 1992) conduct empirical study on relationship between per capita income growth rates and foreign direct investment as a share of GDP for data set of 78 developing countries. Other regressors were sahre of investment in GDP, share of machinery and transport equipment in GDP. They conclude that FDI has strong positive relatonship with growth, moreover that FDI leads rather than follow compared to physical capital accumulation solely.

In his seminal paper (Romer P. , Idea Gaps and Object Gaps in Economic Development, 1993) also refers to (Blomstrom, Lipsey, & Zejan, 1992) study and asserts that there exist significant idea gaps between poor and rich countries and thus FDI can facilitate both technological transfers and business knowhow to under developed countries. And these transfers may increase productivity of companies not just receiving the investment but also other players in the economy.

(Aitken & Harrison, 1999) study firm level impact of FDI for a panel of 4000 Venezuelan firms for the period 1975 – 1989 and find no evidence of positive technology spillovers from foreign firms to domestically owned firms.

On the other hand country level studies on FDI and economic growth generally suggest positive relation. For example (Borensztein, De Gregorio, & Lee, 1998) use panel data data for 69 developing countries for the period 1970-1989 to study effect of FDI on growth using Seemingly Unrelated Regression (SUR). They find positive results and argue that FDI has a positive growth-effect when the country has a highly educated workforce that allows it to exploit FDI spillovers.

(Sadik & Bolbol, 2001) apply Ordinary Least Squares (OLS) on data of 6 Arab countries for the years 1978-1998 to study effect of FDI on output. They conclude that while FDI has positive effect on capital accumulation and growth, but has no noticeable effect improving total factor productivity and/or investment efficiency.

(Carkovic & Levine, 2002) on the other hand warn that macroeconomic findings on growth and FDI must be viewed skeptically. They claim that previous studies do not fully control for simultaneity bias, country-specific effects, and the routine use of lagged dependent variables in growth regressions. They use GMM panel estimator which exploits the time-series variation in the data, accounts for unobserved country-specific effects, allows for the inclusion of lagged dependent variables as regressors, and controls for endogeneity of all the explanatory variables, including international capital flows. They conclude that there is no reliable cross country empirical evidence supporting the claim that FDI accelerates economic growth.

(Liu & Wang, 2003) use endogenous growth model specification to study impact of foreign direct investment (FDI) on total factor productivity (TFP) for a cross section of Chinese industrial sectors obtained from public sensus data at 1995. They hypothesize that TFP is affected by the level of Reserach and development (R&D), foreign presence (RFDI), human capital (H) and firm size (FS). They specify a log linear model and apply the OLS method to estimate the TFP equation since endogeneity tests conclude no evidence for two-way link between TFP and the foreign presence. They conclude that foreign presence, the level of R&D and the firm size are the most important factors enhancing TFP in Chinese industries. The findings from this study support the argument that attracting FDI is an effective way of introducing advanced technology to host countries.

(Liu Z. , 2008) the endogenous growth framework, we offer an explanation on how foreign direct investment. (FDI) generates externalities via technology transfer. They empirically test a linear fixed-effects specification where dependent variable is Total factor productivity. An interaction term between the time trend and sectoral FDI is defined to measure relation between long run productivity growth and FDI. Sample consists unbalanced panel of manufacturing firms in China for the period 1995 to 1999 with a total of 50,667 observations. Proxy for spillovers of foreign investment in manufacturing sectors is defined by taking average of the percentage of firm's equity owned by foreign investors, weighted by each firm's share in sector's output. They conclude that an increase in FDI at industry level lowers the short-term productivity level but raises the long-term rate of productivity growth of domestic firms in the same industry.

3.2 The Derivation of Model Sprecification at Balanced Growth Path for Empirical Analysis

In order to be able to compare and contrast effects of Foreign Direct Investment and Financial Innovation variables, we build on the endogenous growth model and specify the same regression with the exception that Financial Innovation variable is replaced by Foreign Direct Investment variable FDI as follows

$$\ln y_{it} = \{(1 - e^{-\beta t})\alpha(1-\theta)\ln s_{it} + (1 - e^{-\beta t})\beta 1 \ln L_{it} + (1 - e^{-\beta t})\phi \ln FDI_{it} + (1 - e^{-\beta t})\ln[\gamma + (1-\alpha)\beta 1 n_{it}] + (1 - e^{-\beta t})\alpha(1-\theta)\ln[(n_{it} + \delta) + \beta 1 n_{it}]\} + e^{-\beta t}\ln y_{it-1} + u_{it} \qquad \textbf{(27)}$$

3.3 Data Description

Real GDP (y), Employment (L), Saving Rate (s), Foreign Direct Investment (FDI) data for 24 OECD member countries through the years 1978 – 2014 has been obtained from World Bank and Penn World Tables, version 9.0 (Feenstra, Inklaar, & Timmer, 2015). Foreign Direct Investment (FDI) variable refers to direct investment equity flows in the reporting economy. It is the sum of equity capital, reinvestment of earnings, and other capital.

Annual FDI variable has been manually convertd to cumulative FDI variable. GDP per worker is manually calculated by dividing real GDP by employment variable. Depreciation rate of capital (delta) and depreciation rate of technological advances (gamma) has been taken constant values of 0,06 and 0,12. The underlying idea is that technological advances will become obsolete much faster compared to capital stock. Since saving rate (s) and growth in labor force (n) are percentages, they have been scaled by multiplying with 100. Since saving rate (s) and growth in labor force (n) are percentages, they have been scaled by multiplying with 100.

Details of data definitions and sources are provided via Table 15 at Appendix.

Table 10 Descriptive statistics for FDI model data:

	y	**L**	**s**	**FDI**	**n**
Mean	66341.41	18.25	25.74	209234	1.14
Median	64087.88	6.04	25.52	37814.18	0.91
Max	160501.1	148.46	56.38	4722811	2.99
Min	23713.55	0.11	8.85	17	0.33
Std. Dev.	22706.12	27.74	4.83	526683.6	0.83
Observations	888	888	888	888	888

Note : GDP per capita is measured in levels, labor force is measured in millions of workers, saving rate is percentage, foreign direct investment is measured in cumulative levels and labor force growth is in percentages.

Table 11 Cross Corelation of Variables

	FDI	L	N	s
FDI	1	0.53	-0.043	-0.18
L		1	-0.07	-0.08
n			1	-0.24
s				1

Note : From the matrix there exist weak negative corelation between saving and cumultive foreign direct investment. In the overall no perfect or high negative or positive corelation between regressors is noted.

3.4 Methodology and Results

Panel data through exploiting both time series and cross-section characteristics presents the researcher with much higher number of data observations compared to pure cross-sectional or time series data sets.

Since model derived and specified in (25) is nonlinear, we have to resort to nonlinear estimation techniques for empirical part of this study.

Considering the panel data set and non-linear nature of the endogenous model specification, iterative optimization technique namely, Panel Nonlinear Least Squares Method with Gauss-Newton Algorithm (GNA) has been used via Eviews9 econometric software.

3.4.1 Results of Data Analysis

As stated earlier, convergence of the nonlinear iterative technique critically depends on starting values of coefficient vector. Therefore panel nonlinear least squares has been simulated for various starting values of coefficient vector which are implied by theory using different step sizes. As a by-product of this simulation study for different starting values implied by macroeconomic theory, Sum of Squared Residual (SSR) values for the converged parameter values were compared. This exercise enabled to determine any converged coefficient values for which SSR objective function is at a local minima rather than a global one for the simulated starting values.

Values of the coefficient vector has been simulated for starting values and step sizes provided in Table 12 below :

Table 12 Simulation values for the coefficient vector in nonlinear least squares estimation

Simulation inputs	Starting Values				
	$(1-e^{-\beta t})$	k^{α}	A^{θ}	FDI^{ϕ}	$Y^{\beta 1}$
	β	**α**	**θ**	**ϕ**	**β1**
Range	0.01 to 0.09	0.1 to 1	0.1 to 0.9	-0.1 to 0.1	0.1 to 0.4
Step size	0.05	0.1	0.1	0.5	0.1

Note : Constant returns to scale in production function implies range of values displayed in table for capital share in GDP denoted by α. Range of values for θ, β1 and ϕ reflect the fact that we allow returns to technology may be increasing or decreasing to scale. Convergence coefficient simulation range of values reflect the view that developed countries are assumed to be at steady state growth phase.

As a result of total 3.600 nonlinear least squares simulations no convergence has been achieved for the above starting values.

Moreover an interaction variable with Human Capital and Foreign Direct Investment was defined as (HC*FDI) simulated since theory implies that one of the channels through which FDI positively effects growth is through knowledge spillovers which accumulates human capital. Simulation results for the same starting values and step sizes given in Table 5 failed to converge. As stated earlier, convergence of the nonlinear iterative technique critically depends on starting values of coefficient vector. Given this outcome simulation was conducted again for a broader range of starting values, for share of per worker capital α and also ϕ which is share of Foreign Direct Investment in technological change.

Values of the coefficient vector has been simulated for starting values and step sizes provided in Table 13 below :

Table 13 Second simulation starting values for the coefficient vector in nonlinear least squares estimation

Simulation inputs	Starting Values				
	$(1-e^{-\beta t})$	k^{α}	A^{θ}	FDI^{ϕ}	$Y^{\beta 1}$
	β	**α**	**θ**	**ϕ**	**β1**
Range	0.01 to 0.09	0.1 to 2.9	0.1 to 0.9	-1 to 3	0.1 to 0.4
Step size	0.05	0.1	0.1	0.05	0.1

Note : Range of values for Convergence coefficient β, scale effects of existing technology level and GDP on technological change denoted by θ and β1 are the same as previous simulation. We extend range of values for α and ϕ.

As a result of total 69.163 nonlinear least squares simulations 1.731 has converged having 6 unique SSR values. and coefficient values whereby results are thus provided via Table 14 below:

Table 14 Second simulation converged results in nonlinear least squares estimation (1)

Simulation Number	Coefficients	Converged Coefficient Values	Sum of Squared Residuals (SSR)	Standard Error	t-statistics
1	β	0.0007	0.1099	0.0004	1.5688
	α	3.1644		2.9445	1.0747
	θ	0.3849		0.6719	0.5729
	β1	0.0949		0.1162	0.8163
	ϕ	-0.3102		0.3102	-1.0001
2	β	0.0004	0.1233	0.0004	1.124
	α	2.3754		1.792	1.3256
	θ	-0.024		1.1842	-0.0203
	β1	0.1624		0.2154	0.754
	ϕ	-0.587		0.6838	-0.8585
3	β	0.0004*	0.1499	0.0002	1.636
	α	1.3095***		0.2342	5.5908
	θ	-0.7835		0.8662	-0.9045
	β1	0.4085		0.2861	1.4281
	ϕ	-0.6557		0.5042	-1.3006
4	β	0.0003	0.1583	0.0002	1.3274
	α	1.2608***		0.2053	6.1407
	θ	-1.1684		1.2944	-0.9026
	β1	0.5307		0.4377	1.2125
	ϕ	-0.9089		0.8092	-1.1232
5	β	0.0002*	0.1788	0.0001	1.8903
	α	1.073***		0.0502	21.3698
	θ	-2.0343*		1.1514	-1.7669
	β1	0.9271*		0.542	1.7106
	ϕ	-1.3717*		0.8017	-1.711
6	β	0.0002**	0.3315	0.0001	2.1066
	α	1.0752***		0.0376	28.5664
	θ	-1.5914**		0.8034	-1.9809
	β1	0.9148*		0.4777	1.9149
	ϕ	-1.0885*		0.5772	-1.8857

(1) Results are sorted according to SSR values in ascending order.

Notes : * is significant at 10%, ** is significant at 5%, *** is significant at 1%.

There are 6 different SSR values, again simulation results fail to predict similar coeffcients altogerther along with same SSR values. The picture here resembles Human Capital results in the sense that again only Convergence coefficient, β estimates are coherently close to one another and SSR values increase for different results. All the other coefficient estimates vary, in some cases change sign and are few significant estmates exist. We are not able to conclude given these results for which the cause may be multiple local optima. Then Gauss Newton Algorithm converges to one of the possible local optimums for the selected starting values.

3.5 CONCLUSION

This study aims to investigate relation between foreing direct investment and per worker income within an endogenous growth model. The ultimate aim to compare and contrast results with those in Chapter 1 where interaction of financial innovation and per worker income was examined. Contributions to literature are using a pure nonlinear specification and also deriving concept of convergence coefficient within the model. Other studies on foreign direct investment used nonlinear estimation such as GMM but an iterative non linear estimation technique has been applied in this study also heavily utilizing results of simulations conducted. Nonlinear estimation of coefficient on FDI variable failed to converge for simulations conducted with different range of starting values implied by theory. Moreover a broader simulation was conducted which returned inconclusive results in the sense that coefficient estimates vary, in some cases change sign and are not statistically significant for majority of estimates. This study stimulates further research on nonlinear estimation of specified model and variables using different iterative algorithms other than Gauss Newton Algorithm (GNA) and also studies on whether Foreign Direct Investment which is generally accepted to have positive relation with growth, interacts positively only within a pure linear and/or log-linearized model setting and not pure nonlinear model specification.

CHAPTER 4 CONCLUSION

In Chapter 1 initially we have set the theoretical background for analyzing relationship between per capita growth and variables of interest namely Financial Innovation (FI), Human Capital (HC) and Foreign Direct Investment (FDI) within a endogenous growth model.

In order to make the concept of Financial Innovation concrete, we have provided detailed examples of 17 financial innovations which were developed from early 19th century to current times. Looking at these examples regarding innovations in financial industry, it became clear that the motivation to continuously innovate new financial products/methods was also a fuel for Information Technology (IT) technology advancements as well. Therefore we defined technology evolution through time proportional to Financial Innovation within the endogenous growth model. Moving on, we derived Balanced Growth Path (BGP) equilibrium constant growth rates in terms of the system parameters which enabled us to solve for Balanced Growth Path equilibrium expressions for per worker physical capital stock and the technology denoted A^g, k^g. Taking a first order Taylor expansion of growth rates around these values we test for stability of the system by both eigenvalue method to find there is saddle path stability. We than solve for eigenvectors explicitly by expressing the system as a 2nd order linear differential equation. As a general solution approach we first solve homogenous equation and then use the initial conditions to find a particular solution. Moreover we also derive the convergence coefficient of the system in terms of the system parameters. Using these solutions for the system we derive time path for per worker income where y(t) is proportional to the level of financial innovation and the level of working people.

We have selected Credit Early Warning Systems as a major financial innovation and made a genuine proxy variable definition for Financial Innovation; $FI_{wit} = \frac{Provision\ on\ Loans_{it}}{\sum Loans_{it}}$ which is different from current literature. Higher values of FI variable would signal poor monitoring of loans and thus ineffective/low level of financial innovation and also lower economic growth. On the other hand lower values of FI variable would mean the opposite. Therefore we expect GDP to move opposite directions with our proxy for financial innovation.

Since our model is nonlinear we used nonlinear least squares method with Gauss Newton Algorithm (GNA) for estimation which is basically an iterative technique.

As a result of total 2.160 nonlinear least squares simulations 470 has converged having the same SSR and coefficient values. We find that financial innovation proxy FI variable has statistically significant coefficient and negative impact on per capita GDP. This result was in line with my expectations since this implies that there is positive relationship between concept of financial innovation and growth. We also find that convergence coefficient to be statistically significant but small in absolute value. Thus we conclude that GDP growth of selected OECD economies will not converge in short run but in the very long run.

In Chapter 2 we used the same theoretical model to empirically test relation between per worker income and another important determinant of endogenous growth theory which is human capital. Our aim was also to contrast and compare results with those of Financial Innovation, if the data converges. We find that on the contrary to FI model results, for the same range of starting points implied by theory, the coefficients do not converge for simulation. Simulation was conducted again for a broader range of starting values, for share of per worker capital α and also ϕ which is share of Human Capital share in change in technology. Results are inconclusive in the sense that coefficient estimates vary, in some cases change sign and are not statistically significant for majority of estimates and not within range of values due to theoretical expectations.

In the 3rd Chapter we tested for the relation between per worker income with Foreign Direct Investment variable within the nonlinear endogenous growth model. Moreover an interaction variable with Human Capital and Foreign Direct Investment (HC*FDI) was also defined and simulated separately. As per theory one of the channels through which FDI positively effects growth is through knowledge spillovers which accumulates human capital. As a result no convergence was achieved for simulated starting points again. Moreover another simulation was conducted again for a broader range of starting values, for share of per worker capital α and also ϕ which is share of FDI in technological change. This time NLS estimates converged by were inconclusive in the sense that different SSR values and coefficient results exist.

This study stimulates further research on topics whether generally accepted positive influencers of growth namely Foreign Direct Investment and Human Capital interact only within a pure linear and/or log-linearized model setting and not pure nonlinear model specification, and also nonlinear estimation of specified model and variables using different iterative algorithms other than Gauss Newton Algorithm (GNA).

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APPENDIX

1. Explicit Derivation of Endogenous Growth Model

1.1 Per worker capital growth derivation :

From (1) we know that

$$Y = AK^{\alpha}L^{1-\alpha} \qquad (1)$$

Multiply the production function with 1/L along with using the property that it is Homogenous of degree 1 in K and L to obtain

$$\frac{Y}{L} = y = A\left(\frac{K}{L}\right)^{\alpha}\left(\frac{L}{L}\right)^{1-\alpha} = Ak^{\alpha} \qquad \textbf{(A1)}$$

where y and k are per worker variables.

The RHS of (4) contains per capita variables only, whereas LHS does not contain per capita variables. Thus it is not an ordinary differential equation that can be solved easily.

$$\frac{\dot{K}}{L} = sy_{it} - \delta k_{it} \qquad (5)$$

In order to transform it into a differential equation in terms of k, we can take time derivative of k = K/L :

$$\dot{k} = \frac{\dot{K}L - \dot{L}K}{L^2} = \frac{\dot{K}}{L} - \frac{\dot{L}}{L}\frac{K}{L} = \frac{\dot{K}}{L} - nk \quad \textbf{(A2)}$$

Substituting (A1) and (A2) into (5) gives us (6)

1.2 Derivation of equations (12) and (13)

Start by differentiating (10) with respect to time :

$s\left[\dot{A}_{it}k_{it}^{\alpha-1} + (\alpha - 1)A_{it}k_{it}^{\alpha-2}\dot{k}_{it}\right] = 0$ since $0 < s <= 1$ and assumed exogenous, expression in brackets equals zero.

Divide through by A_{it} and $k_{it}^{\alpha-1}$ to obtain (12)

Now differentiate (11) with respect to time :

$$\beta 1 Y_{it}^{\beta 1-1}\dot{Y}_{it}FI_{it}^{\phi}A_{it}^{\theta-1} + (\theta - 1)A_{it}^{\theta-2}\dot{A}_{it}Y_{it}^{\beta 1}FI_{it}^{\phi} = 0$$

Divide through by $Y_{it}^{\beta 1}$, $A_{it}^{\theta-1}$ and cancel out $FI_{wit}^{\phi}$to obtain (13).

Shorter way is to take logs of both sides of the equations and then differentiate with respect to time.

1.3 Derivation of Balanced Growth Equilibrium growth rates of per worker physical capital and technology expressed by model parameters

We know that :

$$Y_{it} = A_{it}K_{it}^{\alpha}L_{it}^{1-\alpha} \qquad (1)$$

$$\dot{K}_{it} = I_{it} - \delta K_{it} = sY_{it} - \delta K_{it} \qquad (4)$$

$$\frac{\dot{k}_{it}}{k_{it}} = sA_{it}k_{it}^{\alpha-1} - (n+\delta) \qquad (6)$$

$$\frac{Y}{L} = y = A\left(\frac{K}{L}\right)^{\alpha}\left(\frac{L}{L}\right)^{1-\alpha} = Ak^{\alpha} \qquad \textbf{(A1)}$$

and

$$\frac{\dot{L}}{L} = n \qquad (*)$$

Take logarithm of (1) and then differentiate with regards to time to obtain:

$$\frac{\dot{Y}}{Y} = \frac{\dot{A}}{A} + \alpha\frac{\dot{K}}{K} + (1-\alpha)\frac{\dot{L}}{L} \qquad \textbf{(A3)}$$

Divide through (4) by K to obtain:

$$\frac{\dot{K_{\imath t}}}{K_{\imath t}} = s\frac{Y_{it}}{K_{it}} - \delta$$

Now multiply numerator and denominator of $\frac{Y_{it}}{K_{it}}$ with 1/L and using (6):

$$\frac{\dot{K_{\imath t}}}{K_{\imath t}} = s\frac{Y_{it}\frac{1}{L}}{K_{it}\frac{1}{L}} - \delta = s\frac{A_{it}k_{it}^{\alpha}}{k_{it}} - \delta = \frac{\dot{k}_{it}}{k_{it}} + \mathrm{n} \qquad \textbf{(A4)}$$

Then insert (*),(A3), (A4) into (13) to get:

$$\beta 1\left(\frac{\dot{A}}{A} + \alpha\left(\frac{\dot{k}_{it}}{k_{it}} + \mathrm{n}\right) + (1-\alpha)n\right) + (\theta - 1)\frac{\dot{A}_{it}}{A_{it}} = 0$$

Using (12) for $\frac{\dot{A}_{it}}{A_{it}}$ we have:

$$\beta 1\left((1-\alpha)\frac{\dot{k}_{it}}{k_{it}} + \alpha\left(\frac{\dot{k}_{it}}{k_{it}} + \mathrm{n}\right) + (1-\alpha)n\right) + (\theta - 1)(1-\alpha)\frac{\dot{k}_{it}}{k_{it}} = 0$$

Simplifying;

$$\beta 1\frac{\dot{k}_{it}}{k_{it}} + \beta 1\mathrm{n} + (\theta - 1)(1-\alpha)\frac{\dot{k}_{it}}{k_{it}} = 0$$

$$\frac{\dot{k}_{it}}{k_{it}} = \frac{\beta 1 n}{(1-\alpha)(1-\theta)-\beta 1} = \Omega_k \qquad (14)$$

Inserting (14) into (12) we obtain:

$$\frac{\dot{A}_{it}}{A_{it}} + (\alpha - 1)\frac{\beta 1 n}{(1-\alpha)(1-\theta)-\beta 1} = 0$$

$$\frac{\dot{A}_{it}}{A_{it}} = \frac{(1-\alpha)\beta 1 n}{(1-\alpha)(1-\theta)-\beta 1} = \Omega_A \qquad (15)$$

1.4 Derivation of balanced growth path levels of A(t) and k(t)

We know

$$sA_{it}k_{it}^{\alpha-1} - (n+\delta) = \Omega_k = \frac{\beta 1 n}{(1-\alpha)(1-\theta)-\beta 1} \qquad (10)$$

$$Y_{it}^{\beta} {FI_{wit}}^{\phi} {A_{it}}^{\theta-1} - \gamma = \Omega_A = \frac{(1-\alpha)\beta 1 n}{(1-\alpha)(1-\theta)-\beta 1} \qquad (11)$$

$$\frac{Y}{L} = y = A\left(\frac{K}{L}\right)^{\alpha}\left(\frac{L}{L}\right)^{1-\alpha} = Ak^{\alpha} \qquad \mathbf{(A1)}$$

$$\mathrm{D} = (1-\alpha)(1-\theta) - \beta 1 \qquad (18)$$

Multiplying both sides of (A1) with 1/k:

$$\frac{1}{k}\frac{Y}{L} = Ak^{\alpha-1}$$

Insert into (10):

$$s\frac{Y}{kL} = \Omega_k + (n+\delta)$$

$$Y = \frac{\Omega_k + (n+\delta)}{s}\ kL \qquad \textbf{(A5)}$$

$$A = \frac{\Omega_k + (n+\delta)}{s}\ k^{(1-\alpha)} \qquad \textbf{(A6)}$$

Insert (A5), (A6) into (11):

$$\left[\frac{\Omega_k + (n+\delta)}{s}\ kL\right]^{\beta 1} \cdot {FI_{wit}}^{\phi} \cdot \left[\frac{\Omega_k + (n+\delta)}{s}\ k^{(1-\alpha)}\right]^{(\theta-1)} = \ \Omega_A + \gamma$$

$$k^{\beta 1+(1-\alpha)(\theta-1)} \cdot \left[\frac{\Omega_k + (n+\delta)}{s}\right]^{\beta 1+(\theta-1)} \cdot L^{\beta 1} \cdot {FI_{wit}}^{\phi} \ = (\Omega_A + \gamma)$$

$$k^{\beta 1+(1-\alpha)(\theta-1)} = (\Omega_A + \gamma) \cdot [\Omega_k + (n+\delta)]^{1-(\theta+\beta 1)} \cdot s^{-[1-(\theta+\beta 1)]} \cdot L^{-\beta 1} \cdot {FI_{wit}}^{-\phi}$$

$$k = (\Omega_A + \gamma)^{\frac{1}{\beta 1+(1-\alpha)(\theta-1)}} \cdot [\Omega_k + (n+\delta)]^{\frac{1-(\theta+\beta 1)}{\beta 1+(1-\alpha)(\theta-1)}} \cdot s^{\frac{-[1-(\theta+\beta 1)]}{\beta 1+(1-\alpha)(\theta-1)}}$$

$$\cdot L^{\frac{-\beta 1}{\beta 1+(1-\alpha)(\theta-1)}} \cdot FI_{wit}{}^{\frac{-\phi}{\beta 1+(1-\alpha)(\theta-1)}}$$

$$k_t^g = \frac{s^{\frac{[1-(\theta+\beta 1)]}{(1-\alpha)(1-\theta)-\beta 1}} . L^{\frac{\beta 1}{(1-\alpha)(1-\theta)-\beta 1}} . FI_{wit}{}^{\frac{\phi}{(1-\alpha)(1-\theta)-\beta 1}}}{(\Omega_A+\gamma)^{\frac{1}{(1-\alpha)(1-\theta)-\beta 1}} . [\Omega_k+(n+\delta)]^{\frac{1-(\theta+\beta 1)}{(1-\alpha)(1-\theta)-\beta 1}}} \qquad (16)$$

Now insert this expression and (14) into (A6) to get:

$$A = \frac{\frac{\beta 1 n}{(1-\alpha)(1-\theta)-\beta 1} + (n+\delta)}{s}$$

$$\cdot \left[\frac{s^{\frac{[1-(\theta+\beta 1)]}{(1-\alpha)(1-\theta)-\beta 1}} \cdot L^{\frac{\beta 1}{(1-\alpha)(1-\theta)-\beta 1}} \cdot FI_{wit}{}^{\frac{\phi}{(1-\alpha)(1-\theta)-\beta 1}}}{(\Omega_A+\gamma)^{\frac{1}{(1-\alpha)(1-\theta)-\beta 1}} \cdot [\Omega_k+(n+\delta)]^{\frac{1-(\theta+\beta 1)}{(1-\alpha)(1-\theta)-\beta 1}}} \right]^{(1-\alpha)}$$

$$A = \left[\frac{\beta 1 n}{(1-\alpha)(1-\theta)-\beta 1} + (n+\delta)\right] \cdot s^{-1}$$

$$\cdot \left[\frac{s^{\frac{[1-(\theta+\beta 1)]}{(1-\alpha)(1-\theta)-\beta 1}} \cdot L^{\frac{\beta 1}{(1-\alpha)(1-\theta)-\beta 1}} \cdot FI_{wit}{}^{\frac{\phi}{(1-\alpha)(1-\theta)-\beta 1}}}{(\Omega_A+\gamma)^{\frac{1}{(1-\alpha)(1-\theta)-\beta 1}} \cdot [\Omega_k+(n+\delta)]^{\frac{1-(\theta+\beta 1)}{(1-\alpha)(1-\theta)-\beta 1}}} \right]^{(1-\alpha)}$$

Here we use $\left[\frac{\beta 1 n}{(1-\alpha)(1-\theta)-\beta 1} + (n+\delta)\right] = \Omega_k + (n+\delta)$

Multiplying similar expressions

$$A = \frac{s^{\frac{[1-(\theta+\beta 1)](1-\alpha)-[(1-\alpha)(1-\theta)-\beta 1]}{(1-\alpha)(1-\theta)-\beta 1}} \cdot L^{\frac{\beta 1(1-\alpha)}{(1-\alpha)(1-\theta)-\beta 1}} \cdot FI_{wit}{}^{\frac{\phi(1-\alpha)}{(1-\alpha)(1-\theta)-\beta 1}}}{(\Omega_A+\gamma)^{\frac{1-\alpha}{(1-\alpha)(1-\theta)-\beta 1}} \cdot [\Omega_k+(n+\delta)]^{\frac{(1-\alpha)(1-\theta)+\beta 1(1-\alpha)}{(1-\alpha)(1-\theta)-\beta 1}-1}}$$

$$A = \frac{s^{\frac{(1-\theta)(1-\alpha)-\beta 1(1-\alpha)-[(1-\alpha)(1-\theta)-\beta 1]}{(1-\alpha)(1-\theta)-\beta 1}} \cdot L^{\frac{\beta 1(1-\alpha)}{(1-\alpha)(1-\theta)-\beta 1}} \cdot FI_{wit}{}^{\frac{\phi(1-\alpha)}{(1-\alpha)(1-\theta)-\beta 1}}}{(\Omega_A+\gamma)^{\frac{1-\alpha}{(1-\alpha)(1-\theta)-\beta 1}} \cdot [\Omega_k+(n+\delta)]^{\frac{\alpha\beta 1}{(1-\alpha)(1-\theta)-\beta 1}}}$$

$$A = \frac{s^{\frac{\alpha\beta 1}{(1-\alpha)(1-\theta)-\beta}} \cdot L^{\frac{\beta 1(1-\alpha)}{(1-\alpha)(1-\theta)-\beta}} \cdot FI_{wit}{}^{\frac{\phi(1-\alpha)}{(1-\alpha)(1-\theta)-\beta 1}}}{(\Omega_A+\gamma)^{\frac{1-\alpha}{(1-\alpha)(1-\theta)-\beta 1}} \cdot [\Omega_k+(n+\delta)]^{\frac{\alpha 1\beta 1}{(1-\alpha)(1-\theta)-\beta 1}}}$$

$$A_t^g = \frac{s^{\frac{\alpha\beta 1}{D}} \cdot L^{\frac{\beta 1(1-\alpha)}{D}} \cdot FI_{wit}{}^{\frac{\phi(1-\alpha)}{D}}}{(\Omega_A+\gamma)^{\frac{1-\alpha}{D}} \cdot [\Omega_k+(n+\delta)]^{\frac{\alpha\beta 1}{D}}} \qquad (17)$$

1.5 Derivation of Log Linear approximation for the model around balanced growth path

The system of differential equations that express dynamics of the model specifying producing via financial innovation is given from equations (10) and (11) by

$$\frac{\dot{k}}{k} = sA_{it}k_{it}^{\alpha-1} - (n+\delta) \equiv \mathrm{g}_k\,(LnA, Lnk) \qquad \textbf{(A7)}$$

$$\frac{\dot{A}}{A} = Y_{it}^{\beta 1}{FI_{wit}}^{\phi}{A_{it}}^{\theta-1} - \gamma \equiv \mathrm{g}_A\,(LnA, Lnk) \qquad \textbf{(A8)}$$

Following (Ulusoy & Yalçın, Convergence of Productivity Levels Among EU Countries : Evidence From A Panel Of Industries, 2011), apply first order Taylor series approximation where production function is $\mathrm{y(t) = A_t k_t^{\alpha}}$. Start by writing the system in terms of Logs of A and k:

$$\frac{\dot{k}}{k} = \frac{d\ln k}{dt} = se^{\ln\left(Ak^{\alpha-1}\right)} - (n+\delta) = se^{\ln(A)+(\alpha-1)\ln k} - (n+\delta)$$

$$\frac{\dot{A}}{A} = \frac{d\ln A}{dt} = {FI_{wit}}^{\phi}e^{\ln(Y_{it}^{\beta 1}{A_{it}}^{\theta-1})} - \gamma = {FI^{\phi}}_{wit}e^{\beta 1\ln(Y_{it})+(\theta-1)\ln A_{it}} - \gamma$$

$$= FI^{\phi}e^{(\beta 1+\theta-1)\ln A+\alpha\beta 1\ln k} - \gamma$$

The first order Taylor expansion around the balanced growth path values A^g, k^g are derived as follows:

Take the partial derivatives with respect to Lnk and LnA.

In following two equations we are also using relation in (10)

$$\frac{\partial\left(\frac{\dot{k}}{k}\right)}{\partial\ln k} = (\alpha-1)se^{\ln(A)+(\alpha-1)\ln k} = (\alpha-1)sAk^{(\alpha-1)} = (\alpha-1)[\Omega_k + (n+\delta)]$$

$$\frac{\partial\left(\frac{\dot{k}}{k}\right)}{\partial \ln A} = se^{\ln(A)+(\alpha-1)\ln k} = sAk^{(\alpha-1)} = [\Omega_k + (n+\delta)]$$

In following two equations we are also using relation in (11)

$$\frac{\partial\left(\frac{\dot{A}}{A}\right)}{\partial \ln k} = FI^{\phi}(\alpha\beta 1)e^{(\beta 1+\theta-1)\ln A+\alpha\beta 1 \ln k} = (\alpha\beta 1)(Ak^{\alpha})^{\beta 1}FI^{\phi}A^{(\theta-1)} = \alpha\beta 1[\Omega_A + \gamma]$$

$$\frac{\partial\left(\frac{\dot{A}}{A}\right)}{\partial \ln A} = FI^{\phi}(\beta 1+\theta-1)e^{(\beta 1+\theta-1)\ln A+\alpha\beta 1 \ln k} = (\beta 1+\theta-1)(Ak^{\alpha})^{\beta 1}FI^{\phi}A^{(\theta-1)} = (\beta 1+\theta-1)[\Omega_A+\gamma]$$

Now write first order Taylor expansion of (A7) and (A8) around A^g, k^g with derived derivatives:

$$\frac{\dot{k}}{k} \approx \Omega_k + (\alpha-1)[\Omega_k + (n+\delta)](\ln k - \ln k^g) + [\Omega_k + (n+\delta)](\ln A - \ln A^g) \quad \textbf{(A9)}$$

$$\frac{\dot{A}}{A} \approx \Omega_A + \alpha\beta 1[\Omega_A+\gamma](\ln k - \ln k^g) + (\beta 1+\theta-1)[\Omega_A+\gamma](\ln A - \ln A^g) \quad \textbf{(A10)}$$

Using matrix notation rewrite the system as the following:

$$\begin{pmatrix}\frac{\dot{k}}{k}\\ \frac{\dot{A}}{A}\end{pmatrix} \approx \begin{pmatrix}\Omega_k\\ \Omega_A\end{pmatrix} + \begin{pmatrix}(\alpha-1)[\Omega_k+(n+\delta)] & [\Omega_k+(n+\delta)]\\ \alpha\beta 1[\Omega_A+\gamma] & (\beta 1+\theta-1)[\Omega_A+\gamma]\end{pmatrix}\begin{pmatrix}\ln k-\ln k^g\\ \ln A-\ln A^g\end{pmatrix}$$

(A11)

Here we adopt (Barro & Sala-i Martin, 2004, s. 33-34,66,132)[9] definition of steady state and also follow (Romer D. , Advanced Macroeconomics, 2012, s. 67-70) in linearizing along the growth path so without loss of generality the system to be solved becomes:

$$\begin{pmatrix}\frac{\dot{k}}{k}\\ \frac{\dot{A}}{A}\end{pmatrix} \approx \begin{pmatrix}(\alpha-1)[\Omega_k+(n+\delta)] & [\Omega_k+(n+\delta)]\\ \alpha\beta 1[\Omega_A+\gamma] & (\beta 1+\theta-1)[\Omega_A+\gamma]\end{pmatrix}\begin{pmatrix}\ln k-\ln k^g\\ \ln A-\ln A^g\end{pmatrix} \quad \textbf{(A12)}$$

In order to solve the system (A12) with eigenvalue method we follow (Sydsæter Knut, 2008) and make the system homogenous by defining new variables measuring deviation from the balanced growth path values:

Let;

$w = \ln k - \ln k^g, \quad w + \ln k^g = \ln k, \ \dot{w} = \frac{d}{dt}(\ln k)$

$z = \ln A - \ln A^g\,, \quad z + \ln A^g = \ln A, \ \dot{z} = \frac{d}{dt}(\ln A)$

---

[9] "We now have the necessary tools to analyze the behavior of the model over time. We first consider the *long run* or *steady state*,, and then we describe the short run or transitional dynamics. We define a steady state as a situation in which the various quantities grow at constant (perhaps zero) rates. Some economists use the expression balanced growth path to describe the state in which all variables grow at a constant rate and use steady state to describe the particular case when the growth rate is zero. In the steady state, where $\frac{d}{dt}\left[\log \hat{k}\right] = \frac{d}{dt}[\log \hat{c}] = 0$. If a steady state exists, the associated growth rate, $\left(\frac{\dot{k}}{k}\right)^*$ is constant by definition."

Substitute these values into (A12) to obtain:

$$\dot{w} = (\alpha - 1)[\Omega_k + (n + \delta)]w + (\alpha - 1)[\Omega_k + (n + \delta)]\ln k^g + [\Omega_k + (n + \delta)]z - [\Omega_k + (n + \delta)]\ln A^g$$

$$\dot{z} = \alpha\beta 1[\Omega_A + \gamma]w + \alpha\beta 1[\Omega_A + \gamma]\ln k^g + (\beta 1 + \theta - 1)[\Omega_A + \gamma]z - (\beta 1 + \theta - 1)[\Omega_A + \gamma]\ln A^g$$

In matrix form:

$$\binom{\dot{w}}{\dot{z}} = \begin{pmatrix} (\alpha - 1)[\Omega_k + (n + \delta)] & [\Omega_k + (n + \delta)] \\ \alpha\beta 1[\Omega_A + \gamma] & (\beta 1 + \theta - 1)[\Omega_A + \gamma] \end{pmatrix} \binom{w}{z} \quad \textbf{(A13)}$$

Let Jacobian matrix first on the right hand side be $\mathbb{A}$, solve $|\mathbb{A}|$ so as to determine *stability properties* of the system:

$$|\mathbb{A}| = \{(\alpha - 1)[\Omega_k + (n + \delta)] \cdot (\beta 1 + \theta - 1)[\Omega_A + \gamma]\} - \{\alpha\beta 1[\Omega_A + \gamma] \cdot [\Omega_k + (n + \delta)]\}$$

where $0 < \theta < 1; 0 < \alpha < 1; 0 < \beta 1 < 1$

Below we examine signs:

$|\mathbb{A}| = \{(\alpha - 1)[\Omega_k + (n + \delta)] \cdot (\beta 1 + \theta - 1)[\Omega_A + \gamma]\} - \{\alpha\beta 1[\Omega_A + \gamma] \cdot$

$[\Omega_k + (n + \delta)]\}$ **(A14)**

- + +,- + -

where conclude that $|\mathbb{A}| < 0$ implying *Saddle Path Stability and thus 2 eigenvalues have opposite signs* for the system (A13).

We will continue solving the system by eigenvalue method. Let:

$w = e^{\lambda t} v_1, \dot{w} = \lambda e^{\lambda t} v_1$

$z = e^{\lambda t} v_2, \dot{z} = \lambda e^{\lambda t} v_2$

Substitute into (A13):

$$\lambda e^{\lambda t}\begin{pmatrix} v_1 \\ v_2 \end{pmatrix} = \begin{pmatrix} (\alpha-1)[\Omega_k+(n+\delta)] & [\Omega_k+(n+\delta)] \\ \alpha\beta1[\Omega_A+\gamma] & (\beta1+\theta-1)[\Omega_A+\gamma] \end{pmatrix} e^{\lambda t}\begin{pmatrix} v_1 \\ v_2 \end{pmatrix}$$

Cancel out $e^{\lambda t}$ and move $\lambda\begin{pmatrix} v_1 \\ v_2 \end{pmatrix}$ to right hand side:

$$\vec{0} = \begin{pmatrix} (\alpha-1)[\Omega_k+(n+\delta)] & [\Omega_k+(n+\delta)] \\ \alpha\beta1[\Omega_A+\gamma] & (\beta1+\theta-1)[\Omega_A+\gamma] \end{pmatrix}\begin{pmatrix} v_1 \\ v_2 \end{pmatrix} - \lambda\begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix}\begin{pmatrix} v_1 \\ v_2 \end{pmatrix} \quad \textbf{(A15)}$$

$$\vec{0} = \begin{pmatrix} (\alpha-1)[\Omega_k+(n+\delta)]-\lambda & [\Omega_k+(n+\delta)] \\ \alpha\beta1[\Omega_A+\gamma] & (\beta1+\theta-1)[\Omega_A+\gamma]-\lambda \end{pmatrix}\begin{pmatrix} v_1 \\ v_2 \end{pmatrix} \qquad \textbf{(A16)}$$

solve $|\mathbb{A}| = 0$ for non trivial solutions. Therefore the characteristic equation becomes:

$$\lambda^2 - \lambda\{(\alpha-1)[\Omega_k+(n+\delta)] + (\beta1+\theta-1)[\Omega_A+\gamma]\} - \{\alpha\beta1[\Omega_A+\gamma]\cdot [\Omega_k+(n+\delta)]\} = 0 \qquad \textbf{(A17)}$$

Solutions for the quadratic equation are:

$$\lambda_{1,2} = \frac{1}{2}\left\{ \left[(\alpha-1)[\Omega_k+(n+\delta)] + (\beta1+\theta-1)[\Omega_A+\gamma]\right] \pm \left(\left[(\alpha-1)[\Omega_k+(n+\delta)] + (\beta1+\theta-1)[\Omega_A+\gamma]\right]^2 + 4\{\alpha\beta1[\Omega_A+\gamma]\cdot[\Omega_k+(n+\delta)]\}\right)^{\frac{1}{2}}\right\}$$

(A18)

Here the first eigenvalue has + sign and second has – sign. We focus on the second eigenvalue so as to obtain saddle path stability and convergence. Notice that *second eigenvalue is identical with speed of convergence defined in* (22).

From $\lambda_{1,2}$ we derive the eigenvectors and the system (A13) has the solution:

$$\binom{w}{z} = \psi_1 e^{\lambda_1 t}\binom{v_1}{v_2} + \psi_2 e^{\lambda_2 t}\binom{u_1}{u_2} \quad \textbf{(A19)}$$

$\psi_{1,2}$ are arbitrary constants of integration. Vectors $\binom{v_1}{v_2}, \binom{u_1}{u_2}$ are eigenvectors associated with relevant eigenvalues.

From (A14) we know there exists saddle path stable solution and $\lambda_{1,2}$ has opposite signs. Since $\lambda_1 > 0$ then $\psi_1 = 0$ must hold for the system (A13) to be stable and thus converge. Note that $\lambda_2 = -\beta$.

For λ_2 associated eigenvector is derived as follows: (Full derivation of eigenvectors is provided in *Appendix 1.6*)

$\binom{u_1}{u_2} = \left(\begin{array}{c} 1 \\ \frac{-\beta 1}{(\Omega_k+(n+\delta))} \end{array}\right)$ substituting this and $\psi_1 = 0$ into (A19) we get

$$\binom{w}{z} = \psi_2 e^{\lambda_2 t}\left(\begin{array}{c} 1 \\ \frac{-\beta 1}{(\Omega_k+(n+\delta))} \end{array}\right) \qquad \textbf{(A20)}$$

Now substitute for original variables:

$w = \ln k - \ln k^g, \; z = \ln A - \ln A^g$

$$\binom{\ln k}{\ln A} = \psi_2 e^{\lambda_2 t} \begin{pmatrix} 1 \\ \frac{-\beta 1}{(\Omega_k + (n+\delta))} \end{pmatrix} + \binom{\ln k^g}{\ln A^g} \qquad \textbf{(A21)}$$

Using the initial condition that $k(0) is$ given:

$$\ln k(0) = \psi_2 e^{\lambda_2 \cdot 0} + \ln k^g$$

(A22)

$$\psi_2 = \ln k(0) - \ln k^g$$

Inserting the expression for $\psi_2$in (A21) we derive solution to the system:

$$\binom{\ln k}{\ln A} = [\ln k(0) - \ln k^g] e^{-\beta t} \begin{pmatrix} 1 \\ \frac{-\beta 1}{(\Omega_k + (n+\delta))} \end{pmatrix} + \binom{\ln k^g}{\ln A^g} \qquad \textbf{(A23)}$$

$$\ln k_t \approx [\ln k(0) - \ln k^g] e^{-\beta t} + \ln k^g$$

(A24)

$$\ln A_t \approx [\ln k(0) - \ln k^g] \frac{-\beta 1}{(\Omega_k + (n+\delta))} e^{-\beta t} + \ln A^g$$

around $\ln k^g$, $\ln A^g$ where

$$-\beta = \frac{1}{2}\left\{ \left[(\alpha-1)[\Omega_k + (n+\delta)] + (\beta1 + \theta - 1)[\Omega_A + \gamma]\right] - \left(\left[(\alpha-1)[\Omega_k + (n+\delta)] + (\beta1 + \theta - 1)[\Omega_A + \gamma]\right]^2 + 4\{\alpha\beta1[\Omega_A + \gamma] \cdot [\Omega_k + (n+\delta)]\}\right)^{\frac{1}{2}} \right\}$$

<u>Next we derive $\ln y_t$ as follows:</u>

$$\text{Since } \ln y_t = \ln A_t + \alpha \ \ln k_t \qquad \textbf{(A25)}$$

Insert expressions for $\ln k_t$ from (A24) into (A25):

$$\ln y_t = \ln A_t + \alpha\left([\ln k(0) - \ln k^g]e^{-\beta t} + \ln k^g\right) \quad \textbf{(A26)}$$

Substitute $\ln k(0)$, $\ln k^g$ from (A25) into (A26),

$$\ln k(0) = \frac{\ln y(0) - \ln A(0)}{\alpha}$$

$$\ln k^g = \frac{\ln y^g - \ln A^g}{\alpha}$$

to obtain:

$$\ln y_t = \ln A_t + \alpha\left(\left[\frac{\ln y(0) - \ln A(0)}{\alpha} - \frac{\ln y^g - \ln A^g}{\alpha}\right]e^{-\beta t} + \frac{\ln y^g - \ln A^g}{\alpha}\right)$$

$$\ln y_t = \ln A_t + \left([\ln y(0) - \ln A(0) - \ln y^g + \ln A^g]e^{-\beta t} + \ln y^g - \ln A^g\right)$$

(A27)

Substitute following from (A24) into (A27)

$$\ln A(t) = [\ln k(0) - \ln k^g] \frac{-\beta 1}{(\Omega_k + (n + \delta))} e^{-\beta t} + \ln A^g$$

$$\ln A(0) = [\ln k(0) - \ln k^g] \frac{-\beta 1}{(\Omega_k + (n + \delta))} + \ln A^g$$

to obtain:

$$\ln y_t = [\ln k(0) - \ln k^g] \frac{-\beta 1}{(\Omega_k + (n + \delta))} e^{-\beta t} + \ln A^g$$
$$+ \left(\left[\ln y(0) - \left\{[\ln k(0) - \ln k^g] \frac{-\beta 1}{(\Omega_k + (n + \delta))} + \ln A^g\right\} - \ln y^g\right.\right.$$
$$\left.\left. + \ln A^g\right] e^{-\beta t} + \ln y^g - \ln A^g\right)$$

Make necessary cancellations to obtain:

$$\ln y(t) = [\ln y(0) - \ln y^g]e^{-\beta t} + \ln y^g$$

$$\ln y(t) = \left[1 - e^{-\beta t}\right] \ln y^g + e^{-\beta t} \ln y(0) \qquad \textbf{(A28)}$$

1.6 Derivation of eigenvectors and speed of convergence of the system (A12) by 2nd order linear differential equation solution:

$$\begin{pmatrix} \frac{\dot{k}}{k} \\ \frac{\dot{A}}{A} \end{pmatrix} \approx \begin{pmatrix} (\alpha - 1)[\Omega_k + (n+\delta)] & [\Omega_k + (n+\delta)] \\ \alpha\beta 1[\Omega_A + \gamma] & (\beta 1 + \theta - 1)[\Omega_A + \gamma] \end{pmatrix} \begin{pmatrix} \ln k - \ln k^g \\ \ln A - \ln A^g \end{pmatrix} \qquad \textbf{(A12)}$$

$$\frac{\dot{k}}{k} = (\alpha - 1)[\Omega_k + (n+\delta)] \ln k - (\alpha - 1)[\Omega_k + (n+\delta)] \ln k^g + [\Omega_k + (n+\delta)] \ln A - [\Omega_k + (n+\delta)] \ln A^g$$

(A29)

$$\frac{\dot{A}}{A} = \alpha\beta 1[\Omega_A + \gamma] \ln k - \alpha\beta 1[\Omega_A + \gamma] \ln k^g + (\beta 1 + \theta - 1)[\Omega_A + \gamma] \ln A - (\beta 1 + \theta - 1)[\Omega_A + \gamma] \ln A^g$$

(A30)

Differentiate (A29):

$$\frac{d}{dt}\left(\frac{\dot{k}}{k}\right) = (\alpha - 1)[\Omega_k + (n+\delta)]\left(\frac{\dot{k}}{k}\right) + [\Omega_k + (n+\delta)]\left(\frac{\dot{A}}{A}\right) \qquad \textbf{(A31)}$$

Insert (A30) into (A31):

$$\frac{d}{dt}\left(\frac{\dot{k}}{k}\right) = (\alpha - 1)[\Omega_k + (n+\delta)]\left(\frac{\dot{k}}{k}\right) + [\Omega_k + (n+\delta)]\{\alpha\beta1[\Omega_A + \gamma]\ln k - \alpha\beta1[\Omega_A + \gamma]\ln k^g + (\beta1 + \theta - 1)[\Omega_A + \gamma]\ln A - (\beta1 + \theta - 1)[\Omega_A + \gamma]\ln A^g\} \qquad \textbf{(A32)}$$

Insert $[\Omega_k + (n+\delta)]\ln A = \frac{\dot{k}}{k} + [\Omega_k + (n+\delta)]\ln A^g - (\alpha - 1)[\Omega_k + (n+\delta)]\ln k + (\alpha - 1)[\Omega_k + (n+\delta)]\ln k^g$ from **(A29)** into **(A32)** cancel out lnA^g terms:

$$\frac{d}{dt}\left(\frac{\dot{k}}{k}\right)$$

$$= (\alpha - 1)[\Omega_k + (n+\delta)]\left(\frac{\dot{k}}{k}\right)$$

$$+ [\Omega_k + (n+\delta)]\alpha\beta1[\Omega_A + \gamma]\ln k - [\Omega_k + (n+\delta)]\alpha\beta1[\Omega_A + \gamma]\ln k^g$$

$$- [\Omega_k + (n+\delta)](\beta1 + \theta - 1)[\Omega_A + \gamma]\ln A^g + \Bigg(\beta1$$

$$+ \theta - 1[\Omega_A + \gamma]\left\{\frac{\dot{k}}{k} + [\Omega_k + (n+\delta)]\ln A^g - (\alpha - 1)[\Omega_k + (n+\delta)]\ln k + (\alpha - 1)[\Omega_k + (n+\delta)]\ln k^g\right\}\Bigg)$$

Grouping similar terms:

$$\frac{d}{dt}\left(\frac{\dot{k}}{k}\right) = \{(\beta 1+\theta-1)[\Omega_A+\gamma] + [\Omega_k+(n+\delta)]\}\left(\frac{\dot{k}}{k}\right) + \{[\Omega_k+(n+\delta)]\alpha\beta 1[\Omega_A+\gamma] - (\beta 1+\theta-1)[\Omega_A+\gamma](\alpha-1)[\Omega_k+(n+\delta)]\}\ln k + \{(\beta 1+\theta-1)[\Omega_A+\gamma](\alpha-1)[\Omega_k+(n+\delta)] - [\Omega_k+(n+\delta)]\alpha\beta 1[\Omega_A+\gamma]\}\ln k^g$$

(A33)

(A33) is a 2nd order ordinary linear differential equation with constant coefficients with general solution:

$$\ddot{x} + a\dot{x} + bx = c$$

$$x(t) = Au_1(t) + Bu_2(t) + u^*(t)$$

We will first solve homogenous equation to $u_1(t), u_2(t)$ and use initial conditions to find A, B and last use method of undetermined coefficients to find particular solution $u_1(t)^*$

Let Lnk=a and the homogenous equation for (A33) becomes:

$$\ddot{a} - \{(\beta 1+\theta-1)[\Omega_A+\gamma] + [\Omega_k+(n+\delta)]\}\dot{a} - \{[\Omega_k+(n+\delta)]\alpha\beta 1[\Omega_A+\gamma] - (\beta 1 + \theta-1)[\Omega_A+\gamma](\alpha-1)[\Omega_k+(n+\delta)]\}a = 0$$

Let $a = e^{rt}, \dot{a} = re^{rt}, \ddot{a} = r^2 e^{rt}$ insert above equation and cancel out e^{rt} so the characteristic equation becomes:

$$r^2 - \{(\beta 1 + \theta - 1)[\Omega_A + \gamma] + [\Omega_k + (n + \delta)]\}r - \{[\Omega_k + (n + \delta)]\alpha\beta 1[\Omega_A + \gamma] - (\beta 1 + \theta - 1)[\Omega_A + \gamma](\alpha - 1)[\Omega_k + (n + \delta)]\} = 0$$

$$r_{1,2} = \frac{1}{2}\Big[\{(\beta 1 + \theta - 1)[\Omega_A + \gamma] + [\Omega_k + (n + \delta)]\} \mp \{\{(\beta 1 + \theta - 1)[\Omega_A + \gamma] + [\Omega_k + (n + \delta)]\}^2 + 4([\Omega_k + (n + \delta)]\alpha\beta 1[\Omega_A + \gamma] - (\beta 1 + \theta - 1)[\Omega_A + \gamma](\alpha - 1)[\Omega_k + (n + \delta)])\}^{\frac{1}{2}}\Big]$$

Solution to the homogenous equation becomes:

$$\ln k(t) = \psi_1 e^{r_1 t} + \psi_2 e^{r_2 t}$$

where r_1, r_2 are solutions equal to $\lambda_{1,2}$ in (A18)

Now we will obtain particular solution:

Let $\ln k(t^*) = c$ where c is a constant. Then $\frac{d}{dt}(\ln k(t^*)) = \frac{d^2}{dt^2}(\ln k(t^*)) = 0$. Insert into (A33):

$\{[\Omega_k + (n+\delta)]\alpha\beta1[\Omega_A + \gamma] - (\beta1 + \theta - 1)[\Omega_A + \gamma](\alpha - 1)[\Omega_k + (n+\delta)]\}c =$
$-\{(\beta1 + \theta - 1)[\Omega_A + \gamma](\alpha - 1)[\Omega_k + (n+\delta)] - [\Omega_k + (n+\delta)]\alpha\beta1[\Omega_A +$
$\gamma]\}\ln k^g$

$$c = \ln k^g$$

So the General Solution for (A33) becomes:

$\ln k(t) = \psi_1 e^{r_1 t} + \psi_2 e^{r_2 t} + \ln k^g$ **(A34)**

Since the system has saddle path stability and $r_1 > 0$ then $\psi_1 = 0$ must hold for $\ln k(t)$ to tend asymptotically to $\ln k^g$.

Moreover using initial condition $\ln k(0)$ is given, insert into (A34) to obtain:

$\ln k(0) = 0 \cdot e^0 + \psi_2 e^0 + \ln k^g$

$\psi_2 = \ln k(0) - \ln k^g$

Substitute $\psi_1 = 0,\ \psi_2 = \ln k(0) - \ln k^g,\quad r_2 = -\beta\ (define\ -\beta = r_2 < 0)$ into (A34) to obtain time path for $\ln k(t)$

$\ln k(t) = (\ln k(0) - \ln k^g)e^{-\beta t} + \ln k^g$

$\ln k(t) = (1 - e^{-\beta t}) \ln k(t)^g \, e^{-\beta t} + e^{-\beta t} \ln k(0)$ **(A35)**

Now lets solve for $\ln A(t)$:

We know,

$[\Omega_k + (n+\delta)] \ln A = \frac{\dot{k}}{k} + [\Omega_k + (n+\delta)] \ln A^g - (\alpha - 1)[\Omega_k + (n + \delta)] \ \ln k + (\alpha - 1)[\Omega_k + (n+\delta)] \ln k^g$ **(A36)**

And obtain $\frac{\dot{k}}{k}$ from (A35):

$\frac{\dot{k}}{k} = 0 + \beta 1 e^{-\beta t} \ln k^g - \ \beta 1 e^{-\beta t} \ln k(0) = \ \beta 1 e^{-\beta t} (\ln k^g - \ln k(0))$ insert into (A36)

$\ln A\,(t) = -\frac{\beta 1}{[\Omega_k + (n+\delta)]} \ (\ln k(0) - \ln k^g) e^{-\beta t} + (1-\alpha)(\ln k(t) - \ln k^g) + \ln A^g$ (given α>0) **(A37)**

Lastly note that we derived from A37 that the system

$$\begin{pmatrix} \frac{\dot{k}}{k} \\ \frac{\dot{A}}{A} \end{pmatrix} \approx \begin{pmatrix} (\alpha-1)[\Omega_k + (n+\delta)] & [\Omega_k + (n+\delta)] \\ \alpha\beta 1 [\Omega_A + \gamma] & (\beta 1 + \theta - 1)[\Omega_A + \gamma] \end{pmatrix} \begin{pmatrix} \ln k - \ln k^g \\ \ln A - \ln A^g \end{pmatrix} \quad \textbf{(A12)}$$

Has solution :

$$\begin{pmatrix} \ln k \\ \ln A \end{pmatrix} = (\ln k(t) - \ln k^g)e^{\lambda_1 t}\begin{pmatrix} 1 \\ \\ (1-\alpha) \end{pmatrix}$$

$$+ (\ln k(0) - \ln k^g)e^{\lambda_2 t}\begin{pmatrix} 1 \\ \\ \dfrac{-\beta 1}{(\Omega_k + (n+\delta))} \end{pmatrix} + \begin{pmatrix} \ln k^g \\ \ln A^g \end{pmatrix}$$

1.7. Derivation Model Specification at Balanced Growth Path for Empirical Analysis

Substitute

$$k_t^g = \frac{s^{\frac{[1-(\theta+\beta1)]}{D}} \cdot L^{\frac{\beta1}{D}} \cdot FI_w{}^{\frac{\phi}{D}}}{[\Omega_A+\gamma]^{\frac{1}{D}} \cdot [\Omega_k+(n+\delta)]^{\frac{1-(\theta+\beta1)}{D}}} \qquad \textbf{(16)}$$

and

$$A_t^g = \frac{s^{\frac{\alpha\beta1}{D}} \cdot L^{\frac{\beta1(1-\alpha)}{D}} \cdot FI_w{}^{\frac{\phi(1-\alpha)}{D}}}{[\Omega_A+\gamma]^{\frac{1-\alpha}{D}} \cdot [\Omega_k+(n+\delta)]^{\frac{\alpha\beta1}{D}}} \qquad \textbf{(17)}$$

where $$\mathrm{D} = (1-\alpha)(1-\theta)-\beta1 \qquad \textbf{(18)}$$

into

$$y(t)^g = A(t)^g[k(t)^g]^\alpha \qquad \textbf{(23)}$$

to obtain

$$y(t)^g = \frac{s^{\frac{\alpha\beta1}{D}} \cdot L^{\frac{\beta1(1-\alpha)}{D}} \cdot FI_w{}^{\frac{\phi(1-\alpha)}{D}}}{[\Omega_A+\gamma]^{\frac{1-\alpha}{D}} \cdot [\Omega_k+(n+\delta)]^{\frac{\alpha\beta1}{D}}} \cdot \left[\frac{s^{\frac{[1-(\theta+\beta1)]}{D}} \cdot L^{\frac{\beta1}{D}} \cdot FI_w{}^{\frac{\phi}{D}}}{[\Omega_A+\gamma]^{\frac{1}{D}} \cdot [\Omega_k+(n+\delta)]^{\frac{1-(\theta+\beta1)}{D}}}\right]^\alpha$$

$$y(t)^g = \frac{s^{\frac{\alpha\beta1+\alpha-\theta\alpha-\alpha\beta1}{D}} \cdot L^{\frac{\beta1-\alpha\beta1+\alpha\beta1)}{D}} \cdot FI_w{}^{\frac{\phi-\alpha\beta1+\alpha\beta1}{D}}}{[\Omega_A+\gamma]^{\frac{1-\alpha+\alpha}{D}} \cdot [\Omega_k+(n+\delta)]^{\frac{\alpha\beta1+\alpha-\alpha\theta-\alpha\beta1}{D}}}$$

Making necessary cancellations in the exponents:

$$y(t)^g = \left[\frac{s^{\alpha(1-\theta)}}{\Omega_A + \gamma} \frac{L^{\beta 1} \cdot {FI_w}^{\phi}}{[\Omega_k + (n+\delta)]^{\alpha(1-\theta)}}\right]^{1/D}$$

Taking the natural logarithm of this value of per worker income along the growth path (24), and plugging this into the equation (21) gives us the empirical setup: [10]

$$\ln y_{it} = \{(1 - e^{-\beta t})\alpha(1-\theta)\ln s_{it} + (1 - e^{-\beta t})\beta 1 \ln L_{it} + (1 - e^{-\beta t})\phi \ln FI_{it} + (1 - e^{-\beta t})\ln[\gamma + (1-\alpha)\beta 1 n_{it}] + (1 - e^{-\beta t})\alpha(1-\theta)\ln[(n_{it} + \delta) + \beta 1 n_{it}]\} + e^{-\beta t}\ln y_{it-1} + u_{it} \qquad \textbf{(25)}$$

[10] Here we follow (Ulusoy & Yalçın, Convergence of Productivity Levels Among EU Countries : Evidence From A Panel Of Industries, 2011) and without loss of generality omit 1/D term when taking logarithm.

2. Tables

Table 15 Data Definitions and Sources

Data Label	Definition	Source
Labor force, total	Total labor force comprises people ages 15 and older who meet the International Labour Organization definition of the economically active population: all people who supply labor for the production of goods and services during a specified period. It includes both the employed and the unemployed. While national practices vary in the treatment of such groups as the armed forces and seasonal or part-time workers, in general the labor force includes the armed forces, the unemployed, and first-time job-seekers, but excludes homemakers and other unpaid caregivers and workers in the informal sector.	http://databank.worldbank.org/data/reports.aspx?source=2&series=SL.TLF.TOTL.IN&country=
GDP per capita (current US$)	GDP per capita is gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data are in current U.S. dollars.	http://data.worldbank.org/indicator/NY.GDP.PCAP.CD?view=chart
Provision on Loans	Statistics are reported at current prices in millions of national currency and in millions of Euros for OECD countries which are members of the Euro zone: Austria, Belgium, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Slovak Republic, Slovenia and Spain.	http://stats.oecd.org/
Loans	Statistics are reported at current prices in millions of national currency and in millions of Euros for OECD countries which are members of the Euro zone: Austria, Belgium, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Slovak Republic, Slovenia and Spain.	http://stats.oecd.org/
Saving Rate	csh_i : Share of gross capital formation at current PPPs ~ Investment/GDP	http://www.rug.nl/ggdc/productivity/pwt/
Real GDP	rgdpna : Real GDP at constant 2011 national prices (in mil. 2011US$)	http://www.rug.nl/ggdc/productivity/pwt/

Employment	emp : Number of persons engaged (in millions)	http://www.rug.nl/ggdc/productivity/pwt/
Depreciation rate	delta :Average depreciation rate of the capital stock	http://www.rug.nl/ggdc/productivity/pwt/
Human Capital	hc : Human capital index, based on years of schooling and returns to education; see Human capital in PWT9.	http://www.rug.nl/ggdc/productivity/pwt/
Foreign direct investment, net inflows (BoP, current US$)	FDI:Foreign direct investment refers to direct investment equity flows in the reporting economy. It is the sum of equity capital, reinvestment of earnings, and other capital. Direct investment is a category of cross-border investment associated with a resident in one economy having control or a significant degree of influence on the management of an enterprise that is resident in another economy. Ownership of 10 percent or more of the ordinary shares of voting stock is the criterion for determining the existence of a direct investment relationship. Data are in current U.S. dollars.	http://data.worldbank.org/indicator/BX.KLT.DINV.CD.WD

Table 16 List of OECD Countries in Sample

OECD countries for FI variable estimations :	Canada, Chile, Denmark, Germany, Italy, Korea Republic, Norway, Poland, Spain, Switzerland, Turkey
OECD countries for HC and FDI variables estimations :	Australia, Austria, Canada, Chile, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Japan, Mexico, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Turkey, United Kingdom, United States