DYNAMIC RELATIONSHIPS BETWEEN IMMIGRANTS AND US GROSS DOMESTIC PRODUCT USING A VECTOR ERROR CORRECTION MODEL (VECM)

A Thesis

by

GANESH REGMI

Submitted to the Office of Graduate and Professional Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

Chair of Committee,	James W. Mjelde
Co-Chair of Committee,	David A. Bessler
Committee Member,	Timothy J. Gronberg
Head of Department,	C. Parr Rosson III

May 2015

Major Subject: Agricultural Economics

ABSTRACT

Debate over immigration including the role visa policies and immigrants play in the US economy, especially effects on wages, gross domestic product (GDP), employment rate, and consumption remain unresolved. This study investigates the dynamic relationships among the selected economic variables and the number of immigrants to the United States. Variables included are annual total number of immigrants, US GDP, investment in education, national hourly wage rate, and energy consumption from 1964 to 2011. These variables are found to be non-stationary via augmented Dicky-Fuller tests and cointegrated with four cointegrating vectors. A vector error correction, therefore, is used in the analysis. Directed acyclic graphs are used to find contemporaneous causal relationships between the variables. DAGs showed, GDP and wage are source of information, energy both receives and provide information in the system, investment in education is only receiver of the information while immigrants are contemporaneously exogenous. Tests of exclusion find all the variables are in the cointegrating space suggesting all variables share long run relationships. Exogeneity test suggests that all variable responses to the perturbations in the long-run relationships.

Result shows that in the short run, wage has a negative reaction to a shock in GDP. All variables except number of immigrants' response positively to one time innovations in investment in education. Increases in immigrants will has a negative effect on the other variables in short-run. The number of immigrants, in the short-run, do not respond in the innovations in the other variables. Similarly, any shock in energy

consumption will not be responded by any the variables in short-run. Forecast error variance decompositions suggest in short-run a variable is mainly explained by itself; as one moves time ahead forecast the share of other variables becomes larger in explaining a variables forecast error. Wages explain a large amount of the variability in investment in education.

All the variables are cointegrated and any policies implemented to increase or decrease a single variable has effect on other rest of the variables. So policy maker should consider the macroeconomic effect in the system.

DEDICATION

To my father, mother and brother who were always there for me.

ACKNOWLEDGEMENTS

I am very grateful to Professor James W. Mjelde, chair of my thesis committee. I like to thank him for his continuous guidance, patience and support for the research. His knowledge and suggestions helped to complete this research. His continuous monitoring and encouragement throughout the period made research time enjoyable. Without his leading and continuous monitoring, I would not be able to complete this research. It is very wonderful experience to work with him. I learned a lot about research and writing which I can't forget forever.

My special appreciation goes to Professor David A. Bessler, co-chair of my thesis. His advice and vast knowledge about time series helped me to guide in the right direction. He was always helpful and quick responsive to me. I would be thankful to him especially about the software and data analysis.

I am grateful to Professor Timothy J. Gronberg, committee member of my thesis. His time and useful advices was very helpful during my research. I really appreciate his acceptance on my thesis committee member and willing to help me despite his busy schedule.

NOMENCLATURE

ADF	Augmented Dickey-Fuller
AIC	Akaike Information Criteria
DAGs	Directed Acyclic Graphs
DF	Dickey-Fuller
ECM	Error Correction Model
FEVD	Forecast Error Variance Decomposition
GDP	Gross Domestic Product
GNP	Gross National Product
HQ	Hannan and Quinn
IRF	Impulse Response Function
LENERGY	Natural Logarithm of Energy Consumption
LGDP	Natural Logarithm of US Gross Domestic Product
LIOE	Natural Logarithm of Investment in Education
LWAGE	Natural Logarithm of Wage
LIMM	Natural Logarithm of Number of Immigrants
OECD	Organization for Economic Co-operation and Development
SIC	Schwarz Information Criteria
US	United States
VAR	Vector Autoregressive
VECM	Vector Error Correction Model

TABLE OF CONTENTS

Page

ABSTRACT ii

DEDICATION iv

ACKNOWLEDGEMENTS v

NOMENCLATURE vi

LIST OF FIGURES ix

LIST OF TABLES x

CHAPTER I INTRODUCTION 1

Objectives 3

CHAPTER II LITERATURE REVIEW 5

Labor and Wages 5
Energy Consumption 14
Investment in Economy Including Education 18

CHAPTER III METHODOLOGY AND DATA DESCRIPTION 25

Order of Integration I(d) 25
VAR Lag Selection 27
Cointegration 28
Impulse Response Function 30
Forecast Error Variance Decompositions 32
Directed Acyclic Graphs (DAGs) 33
Descriptive Data Statistics 35

CHAPTER IV RESULTS 40

Order of Integration I(d) 40
VECM 41
Post-Estimation Analysis 45
Contemporaneous Structure 48
Impulse Response Functions 50
Forecast Error Variance Decompositions 54

CHAPTER V CONCLUSIONS AND DISCUSSION.....58

Limitations and Further Research 63

REFERENCES.....66

APPENDIX 85

LIST OF FIGURES

FIGURE Page

3.1. Plots of natural logarithm GDP, legal immigrant number, government investment in education, hourly wage, and energy consumption in US 38

3.2. Plots of real GDP, yearly legal immigrant's number, government investment in education, hourly wage, and energy consumption in US. 39

4.1. SIC and HQ loss functions from VECM models with rank one to five for lags one to three and associated loss metrics. 44

4.2. Contemporaneous causal relationships of the variables obtained from PC algorithm with alpha 0.2 and depth of -1.. 50

4.3. Impulse response function; innovation is applied to the column heading variables and responses are shown by the row heading variables.....53

LIST OF TABLES

TABLE Page

3.1. Descriptive Statistics of Natural Logarithm of Real GDP, Number of Immigrants, Real Investment in Education (IOE), Energy Consumption, and Real Natural Wage Rate. 36

3.2. Descriptive Statistics of US Real GDP, Real Natural Wage Rate, Energy Consumption, Real Investment in Education, and Immigration.. 37

4.1. Augmented Dickey-Fuller Tests for Stationarity of Natural Logarithm of GDP, Investment in Education, Wage Rate, Energy Consumption and Immigrant Numbers, Annual Data from 1964 to 2011. 41

4.2. Lag Length Determination for the VECM Model Using SIC and HQ. 42

4.3. Johansen Test of Cointegration for The Model with Lag Length Two and Ranks One Through Five. 42

4.4. SIC and HQ Information Criteria for VECM Including Lags One to Three and Rank One Through Five for Each Lag 43

4.5. Tests of Stationarity of the Variables in Levels VECM with Lag Two and Rank Four.for Annual Data from 1964 to 2011. 46

4.6. Tests of Exclusion of Each Variable From the Cointegrating Space in the VECM Annual Data from 1964 to 2011……..…..……..…….....…..47

4.7. Test of Weak Exogeneity of Each Variable in the Cointegrating Space.....48

4.8. Residual Standard Error and Cross-Correlations Matrix of the Residuals From VECM Model. 49

4.9. Forecast Error Variance Decompositions for LGDP, LIOE, LWAGE, LENERGY, And LIMM For Six Years. 57

CHAPTER I

INTRODUCTION

Economically speaking, migration is the movement of a factor of production from one location to other location where the factor will bring a higher net return (Krugman 1979; Davin 1999; Meyer 2001). In the literature, migration commonly refers to the notion of humans moving from one place to another to better their life style. The Heckscher-Ohlin-Samuelson (H-O-S) model supports this notion that migration of humans can be considered resource mobility of labor (Heckscher and Ohlin 1991; Mussa 1995). If there are no obstacles to mobility, mobility should equalize factor prices worldwide. Despite the globalized economy, not all factors of production are freely movable. Government policies, for example, can impede the mobility of labor creating different equilibrium points around the world.

Immigrants may affect economic growth. According to Malthusian theory, with technology and capital held constant, the labor demand in an economy is downward sloping. If resources are held fixed and labor is constantly increasing, ultimately the productivity of the labor will decrease because of diminishing marginal returns (Malthus 1888). This theory has some simplifying assumptions, primarily all labor is homogenous and other things are held constant. The labor market is a medley of heterogeneous labor forces. Further, technology is dynamic ever changing; advancements in technology increases the efficiency of the available resources. Increasing productivity expands the economy as a whole with the same level of human resources available.

Two opposing trains of thought concerning the economic contributions of immigrants to American society are found. Proponents of immigrants suggest new immigrants contribute to the workforce and to research and development (Borjas, Freeman and Katz 1992). Many proponents believe that immigrants are a necessary component of the lower paying labor market to make the American economy competitive in the global economy, because the majority of immigrants are less skilled and less educated than the general labor force (LaLonde and Topel 1992). Borjas (1999), for example, argues that the agriculture sector of California would not be where it is today and the price of goods would be higher if the US was without low skilled immigrants. Mines and Martin (1984) show the share of Mexican labor in the citrus industry in Ventura County of California increased during 1970s. The increase in immigrants produced welfare gains by increasing firms' profits, lowering the price of goods to consumers, increasing wages of skilled manpower which are complimentary to the lower skilled worker, and lowering the unemployment of skilled man power (Borjas 1994; Friedberg and Hunt 1995).

Opponents argue immigrants hurt the US socially and economically (Card 2005; Citrin et al. 1997). Immigrants compete for jobs with nonimmigrants, lower the quality of life, undermine moral standards, and do not completely assimilate into society (Briggs and Moore 1994; Dustmann, Glitz and Frattini 2008). Another downside of immigration is the burden immigrants may place on government programs and resources. Both legal and illegal low income immigrants pay fewer taxes than the average citizen, but immigrants may use schools and other government facilities and programs more

intensive because of family size and language issues (Citrin et al. 1997; Massey 2008; Simon 1999).

When considering benefits and costs of immigrants for the whole economy, the overall effect may be positive but small. George Borjas stated the average American's wealth is increased by less than one percent because of illegal immigration (Borjas 1994). More hands working means more production in labor intensive industries. Increased production leads to the increase in products produced inside the country. Production of more goods inside country decreases on the demand of goods from abroad. This ultimately reduces imports (Girma and Yu, 2002; Rauch 2001).

Studies have calculated the size of the gain from immigration. Borjas (1995) estimated that 10 percent of the American work force who are immigrants added 0.1 percent to GDP or about $7 billion out of a $7 trillion economy. His estimates are based on the assumption that there is no response to supply of capital to immigrant induced higher return industries. Johnson (1997) estimates 10 percent increase in immigrants will increase output accruing to natives by $2.5 billion or about 0.036 percent of GDP. Gilder (2012) claims that the economies of states where more immigrants live have a higher percentage increase in economic growth compared to the states where there are fewer immigrants.

Objectives

The objective of this study is to identify the effect of immigration on the US economy through establishing dynamic relationships between selected economic variables and immigration. To achieve this objective, a vector error correction model (VECM) is

developed. The advantage of using a VECM is both short-run and long-run relationships between non-stationary variables can be obtained (Hill, Griffiths and Lim 2008). Previous studies have suggested these series are non-stationary and cointegrated. VECM, therefore, is better candidate to model for the non-stationary time series variables. The VECM contains five annual series: real Gross Domestic Product (GDP), number of immigrants each year, average real wage rate in terms of real dollars per hour, energy consumption, and real government investment in education.

Directed acyclic graphs (DAGs) are used to provide instantaneous direction of causality for use in innovation accounting. DAGs gives idea about source and sink of information at contemporaneous time. Information source leads and sink will receive information. Impulse response functions and forecast error variance decompositions. Innovation accounting procedures provide the dynamic nature of the system. If the variables are closely related, an innovation in one series will have a direct and impact on the other, if not then the innovation will not significantly impact the other variables. Variance decomposition analysis breakdowns the source of variance in the dependent variables arising from the independent variables including itself in the system of equations.

CHAPTER II

LITERATURE REVIEW

Numerous studies have examined the impact of immigration on the economy. Literature reviewed is categorized by how immigration may influence labor and wage rates, energy consumption, and investment in the economy including government expenditure in education. Total government spending in education is a part of government spending. So, investing more money in education will contribute on research and development including academic field and non-economic field as research workers. This will also bring more immigrants in US as skilled workers.

Labor and Wages

Migration, the flow of human capital from one place to another, generally occurs from lesser developed to the more developed economies as immigrants search for an improved quality of life. Both skilled, educated workers and unskilled, lesser educated workers migrate. Immigration from lesser technically affluent countries to higher technologically adopting country may increase human efficiency by four to five times, allowing the efficient use of human capital given current technology (Clemens, Montenegro and Pritchette 2009). Such movement increases the labor force in the destination country with a corresponding decrease in labor force in the migrating country (Jokisch and Pribilsky 2002; Martin and Richards 1980). Movement of people is also associated with the transfer of knowledge, skills, and changes in the gradient of these parameters between regions (Iredale 2001; Lopez and Schiff 1998). Docquier, Özden and Peri (2010) show

higher educated people are more likely to migrate than people with less education. They estimate that of the total number of migrants, educated people are four to five times more likely to migrate than people who are less educated. Effects of immigrants on the labor market depend on the skills they pose, knowledge, and substitutability between native and immigrant workers. Grogger and Hanson (2011) claim that migrating populations consists of mostly young people. These young and educated people are attracted by the higher returns on their investment in education. Because of the relatively larger wage premiums paid by American research institutes and private companies, the US attracts the educated from around the world (Autor, Katz and Kearney 2008; Borjas 2003; Chiquiar and Hanson 2002; Zavodny 1999). Among the highly educated and research group, foreign born workers are in higher proportion in US than are other groups (Peri and Sparber 2009).

Heterogeneity in terms of skills in the labor market is required for a healthy and stable economy (Heckman, Lochner and Taber 1998; Kuznets 1957). In the US labor market, there are differences in skills and productivity of the different labor groups. Immigrants generally have lower communication skills and are less familiar with US technology. They often work in low skilled jobs that do not require good communication skills (Gallo 2002; Jandt 2012). This forces native workers to specialize in jobs which require better communication skills (Peri and Sparber 2009). Familiar with the existing technology and good communication skills protects natives from immigrants taking their jobs. Because of skill differences, immigrants and natives can divide the labor force in

two groups. This division increases the efficiency and effectiveness of available labor (D'Amuri and Peri 2011).

The labor force is often divided into two categories to study the relative wages based on skills and institutions involved (Acemoglu 2002; Card 2009; Goldin and Katz 2007; Katz and Murphy 1992). Another aspect of skilled immigrants is they tend to increase the wages of low skilled labor if low skilled labor is a complement to higher skilled labor (Altonji and Card 1991; Juhn, Murphy and Pierce 1993). An extensive literature review regarding the impact of immigration on the domestic labor market is found in the meta-analysis by Longhi, Nijkamp and Poot (2008). This meta-analysis includes 1,572 size effects from 45 studies including 905 size effects from the US. Based on the US studies, non-significant little or no negative effects of immigration on employment and wage of native worker are found by Altonji and Card (1991), Butcher and Card (1991), Card (2001, 2005), Card and DiNardo (2000), and LaLonde and Topel (1991). Other studies find that increasing immigrants have negative, significant effects on domestic worker's wage and employment (Borjas, Freemann and Katz 1996; Borjas et. al 1997; Borjas et al. 1997; Borjas 2003; Aydemir and Borjas 2006). Aydemir and Borjas (2006) also found wage inequality is increasing over the time because of family reunions of less skilled immigrants, but an opposite result is found in Canada; Canada is focusing on skill based immigrants. He claims that, bringing families of low skilled workers increases the low skilled labor supply whereas bringing family of skilled immigrants increases the labor for skilled worker and less skilled worker as well.

Because, low skilled labor does not need any formal training and experience any people can easily be the competitor of already existing low skilled labor market.

Card (2005) found very little, if any, adverse effects of immigration on native workers. This conclusion is based on 2000 census data for 300 metropolitan areas, based on the differences across a large number of local labor markets. If skilled domestic labors are complements to the unskilled immigrants, then increases in the number of immigrants will increase the wage rate and the demand for skilled domestic workers. Twenty percent of the native work force falls in the substitute group of immigrants which is considered as low skilled man power and 80 percent are complements (Smith and Edmoston 1997). An increase in unskilled immigrants, however, may decrease the wages of unskilled native workers. Unskilled labor will have a displacement effect on native workers. Small positive effect of immigration on less educated native workers wage are found (D'Amuri and Peri 2011; Ottaviano and Peri 2012).

Chellaraj, Maskus and Mattoo (2005) calculate that if immigration to developed countries is increased by three percent, the effect would be a net gain of $356 billion for developed countries by year 2025. The total gain from international mobility of labor is greater than gains from international trade even if trade is fully liberalized (Pritchett 2006). Hatfield (2004) identifies recent immigrants as having low incomes and their total incomes being less than the after tax transfer income. If there is large number of high skilled, educated workers as immigrants and if their skills are identified and utilized, these immigrants compete with the high skilled domestic worker as a result incomes of skilled native workers would fall (Jaeger 1996).

Immigration not only affects the local labor market, but also may cause internal migration, the outflow of native workers in response to immigration which in turn influences the geographical distribution of the national labor supply. Larger the outflow of natives because of increased number of immigrants in local area, the smaller will be the effect of immigrants on the local labor market. Several studies quantify the effect of immigrants on outflows (Card 1996; Filer 1992; Frey and Liaw 1998; White and Hunter 1993; White and Liang 1998). These studies do not reach a consensus on how and whether immigration has caused outflows. Filer (1992) and White and Liang (1998) suggest that the native outflow is higher in the areas where immigrants clusters are higher. Frey (1995) in analyzing 1990 census data concluded that there is strong negative correlation between net native's outflows and net immigration. Using the same census data, Card (1996) reports the cross city correlation between the rate of growth of native workers and rate of growth of the number of immigrants is positive for the years 1985-1990. Bartel (1989) finds the negative economic impact of immigrants on the city where they choose to reside is statistically insignificant. Immigrants tend to choose cities where there are already more immigrants (Greenwood and McDowell 1986).

Geographical clustering of immigrants allows one to measure the impact of immigrants on the labor market opportunities of native worker by comparing natives who live in higher dense immigrants areas to natives residing in the cities where fewer immigrants reside. Borjas, Freeman and Katz (1996) show geography also plays a vital role in the wage effect. The immigration wage effect is smaller when compare at the metropolitan area than at the state or national level. The effect is more negative when

compared across states and even a lager negative correlation when the comparison is made across regions. These results are reasonable because spatial correlation is found when calculated at city level may be smaller than when calculated at the regional and state level, because capital and workers are relatively more mobile between cities than regions. The correlation will be even larger at the international level, because it is relatively more expensive to move across countries.

Altonji and Card (1991) show that the share of low wage manufacturing industries has increased in the areas of cities where more immigrants live relative to areas where less immigrants live. Displacement of native workers from a particular industry and area and inflow of immigrants diffuses the labor impact over the entire country. Accrued benefits from consuming goods made from cheap immigrant labor exceed the losses suffered by the native worker. Overall, society will be better off with immigration, although any particular labor group may not benefit (Borjas 1999).

The conclusion from previous research is the average income of natives is slightly lower in states where there are more immigrants residing. Defreitas (1988) and Greenwood and Hunt (1995) find the elasticity of native wage with respect to number of immigrants clusters around zero. LaLonde and Topel (1992) estimate a 10 percent increase in the number of immigrants is associated with a decrease of six percent in black workers' wages. Many studies focus on the relationship between wages of natives and percent share of immigrants in the labor market. Borjas (1994) using cross city panel data shows a weak relation between unemployment rate and total number of hours worked by immigrants. Altonji and Card (1991) found a 10 percent increase in

immigrant number in a local labor market decreases the number of weeks worked by less skilled native workers by 0.6 percent. An intense and abrupt change in immigrant population for a particular city was the Mariel flow to Miami. Because of this flow, Miami's labor force suddenly increased by seven percent (Leibfritz, Obrien and Dumont 2003). Castro (2002), in analyzing on the effect of the Mariel on Miami labor market, concludes the sudden increase of seven percent barely nudged the trend in wages and employment opportunities.

Larger numbers of unskilled workers may be responsible for widening the wage gap between unskilled and skilled labor (Card and DiNardo 2002; Friedberg 2001). Higher returns to skilled labor make human capital investment more attractive for the skills acquisition for both natives and immigrants. Changes in the structure of the labor market are widening the gap between skilled and unskilled; further, the gap is not same for all immigrants (Murphy and Welch 1992). Numerous studies suggest there is a weak relationship between the number of immigrants and wages of natives including black, skilled, unskilled, male, and female (Card 2001; Borjas 2003; Mühleisen and Zimmermann 1994). The group that suffers most from increasing the number of immigrant is low skilled or unskilled black people (Altoni and Card 1991; Grossman 1982). A 10 percent increase in immigrants number decreases immigrants' wages between two percent (Grossman 1982) and four percent (Altoni and Card 1991). Literature on labor demand (reviewed by Hamermesh and Biddle 1993) has suggested that 10 percent increase in immigrant supply would reduce wages by about three percent.

Krugman and Lawrence (1994) estimate that 20 percent of the labor force is directly associated with the trade related activities. Stolper and Samuelson (1941) develop a model to determine the impact of changing import prices on wage inequality by varying the ratio of skilled to unskilled labor wages for different industries. The substitutability between native and immigrants determines the wage. There is evidence that the wage gap between skilled and unskilled is widening (Blackburn, Broom and Freeman 1989; Blum 2008; Davis and Haltiwanger 1991; Goldin and Katz 2007; Harrigan and Balaban 1999; Harrigan 2000). Davis and Haltiwanger (1991) state this widening gap appears to be within an industry, but is not apparent between industries. According to H-O-S model, decreases in the prices of labor intensive goods cause the labor wage to decrease. If the H-O-S model holds, industries should hire more unskilled labor to expand the labor intensive production process. But these results may not hold up empirically. Off-shore sourcing sends the low-skilled production process outside the US. This globalization has increased the wage level of skilled labor and pushes unskilled labor to compete with international unskilled labor (Feenstra and Hanson 1997).

Borjas (1994), Friedberg and Hunt (1995), and Greenwood (1993) compares the spatial correlation between wages of immigrants residing in states with larger immigrant population with states that are more sparsely populated with immigrants. They found the positive correlations between immigrants and hourly wage and employment. Borjas (2001) calculates the labor market was robust in the immigrant intense states during 1970's. Inflows of immigrants are positively related with wages in 1970s, while a negative correlation was found during 1980s. Numerous studies quantify the

immigrants' effect on wages especially of the less skilled workers such as black communities (Card 1989; Borjas, Grogger and Hanson 2010; McCall 2001; Reischauer 1989). Evidence provided by spatial correlation does not indicate any significant reduction of wages in black communities caused by immigration. A number of problems arise using spatial correlation between increasing population of immigrants and native wage. The main problem is comparisons of economic conditions between different areas assume the economy is closed (once migration takes place) and the flow of people is exogenous. This assumption is questionable because capital, labor, and other resources flow across areas to equalize factor price ratios. In the migration case, people migrate toward the areas where the opportunity cost is higher for their skill. Inflow of immigrants in certain areas forces natives to look for better opportunities in other places (domestic migration) and specialize in the fields where they have an advantage.

Most research views labor as a source of factor of production in the whole economy, not just at the local level. Extensive simulation results are that the increase of unskilled to skilled labor ratio with the wage ratio of those groups (Borjas et. al. 1997). Borjas et.al (1997) and Borjas, Freeman and Katz (1992) adopt this approach considering labor force for whole economy to simulate the macroeconomic effect of immigrants using population surveys and decennial census data. Their conclusion is the wage gap between skilled and unskilled labor has increased over time because of the increased number of high school dropouts and less educated people including immigrants. They calculated that the wage gap of skilled and unskilled worker has increased by 19 percent during the period of their data. This result applies for skilled and unskilled domestic and immigrant

workers when categorized in a group. Smith and Edmonston (1997) estimate that immigration alone would have increased this gap by less than 1 percent.

Energy Consumption

Similar to immigration, the effect of energy consumption on an economy has competing inferences in the literature. Decreases in energy consumption may impede economic growth of a country (Yuan, Liu and Xie 2010; Zhang and Cheng 2009). Ang (2007), Apergis and Payne (2009), and Mishra, Smyth and Sharma (2009) claim there is unidirectional causality running from energy consumption to economic growth. The polar inference is that increased energy consumption is detrimental to economic growth because of the shift in production pattern towards services which requires less energy for production (Pradhan 2010). Karanfil (2009) and Payne (2010) state there is no causal between energy consumption and economic growth. The lack of any causality direction between GDP and energy consumption bolsters the neutrality hypothesis. Increases or decreases in GDP or energy consumption is independent of changes in the other; therefore, any changes in energy policies have little to no impact on economic growth (Belloumi 2009; Paul and Bhattacharya 2004; Yu and Jin 1992).

Kraft and Kraft (1978) analyze US data from 1947 to 1974 to determine the relationship between Gross National Product (GNP) and energy consumption. They concluded that GNP is leading energy consumption. Their result, however, is refuted by Akarca and Long (1979) and Yu and Hwang (1984) who claim the result is spurious. Using data from 1973 to 1979, Akarca and Long (1979) show that energy consumption leads employment in the US. They use employment as a proxy for economic growth.

Akarca and Long (1979), Erol and Yu (1987), Yu and Choi (1985), Yu and Hwang (1984), and Yu and Jin (1992) find a neutral relation between energy consumption and economic growth. Similarly, Odhiambo (2009) conclude there is no association between energy consumption and economic growth.

Masih and Masih (1997) applied Johansen cointegration test to analyze if energy consumption and real GDP are cointegrated. They use data from India, Pakistan, Taiwan, South Korea, Singapore, Malaysia, Philippines, and Indonesia from 1955 to 1990. There is no cointegration in Malaysia, Singapore, and Philippines; thus, no long-run relationship exists between these variables. In India, the variables are cointegrated which suggests a long-run relationship between energy consumption and economic growth. Using VECM, they attempt to determine the direction of causality. There is unidirectional causality running from energy consumption to economic growth. In Indonesia, the variables are also cointegrated, but there is unidirectional relationship running from GDP to energy consumption. They also show a bilateral causality between energy consumption and economic growth in Pakistan, Taiwan, and South Korea. Masih and Masih (1998) and Narayan and Prasad (2008) find a feedback relationship between the economic growth and energy consumption, using a panel autoregressive distributed lag model for the Eastern European countries.

Cheng and Lai (1997) analyze data from Taiwan from 1955 to 1993 by using Engle-Granger cointegration tests. They find that the variables are cointegrated and there is causality between the variables. Unidirectional causality running from GDP to energy consumption is found for Taiwan. Furthermore, Yang (2000) also analysis the Taiwan

data from 1954 to 1997 using Engle-Granger cointegration method, but uses Final Prediction Error (FPE) version of Hsiao (1981) to select the optimal lag. He found the two-way causality between economic growth and energy consumption.

Glasure (2002) and Lee (2005) used an error correction model (ECM) to establish the relationship between economic growth and energy consumption in South Korea and Philippines. They found bilateral causality. If they do not include a cointegrating relationship (use a VAR model), neutrality is found for South Korea and unidirectional causality running from energy consumption and GDP growth is found for the Philippines. Asafu-Adjaye (2000) also adopted Johansen cointegration test and Granger causality method to investigate the relationship between energy consumption and economic growth for India, Indonesia, Philippines, and Thailand. Thailand and Philippines showed bilateral causality, while India and Indonesia show unidirectional causality from running from energy consumption to economic growth. Hondroyiannis, Lolos and Papatetrou (2002) analyze data from Greece for 1960 through 1996 using an error correction model to assess the relationship between economic growth and energy consumption. They do not find a short term relationship, but find a long-run relationship. Soytas and Sari (2003) analyze data from 1950 to 1992 for the top 10 economically emerging countries (not including China) and G-7 countries. They find two-way causality for Argentina, one-way causality for Turkey, Japan, Germany, and France with energy leading GDP. GDP leads energy consumption in Italy and Korea.

Aslan, Apergis and Yildirim (2013) using US quarterly data from 1973 to 2012 find the relationship between energy and GDP varies over time. In the short-run, GDP

is leading energy consumption, while in the medium and long-run there is unidirectional causality running from energy consumption to economic growth. Lee (2005) using panel, cointegration analysis, found unidirectional causal relationship from energy consumption to economic growth in both the short-run and long-run for developing countries. Lee (2006) analyzes data from 11 developed countries for 1960 to 2001. Different countries show different relationships between GDP and energy consumption. His results are: (1) feedback relationship between variables for US; (2) energy consumption led GDP for the countries of Canada, Belgium, Netherlands, and Switzerland; (3) unidirectional causality running from GDP to energy consumption is found for Japan, France, and Italy; and (4) for Sweden, Germany, and U.K. no causality between the variables are found.

Lee and Chang (2007) investigate the causality between energy and GDP for 18 developing and 22 developed countries using a panel VAR model. There was one-way causality running from GDP to energy in developing countries, while two-way causality is found for developed countries.

Even for the same country the direction of causality found may different between studies. The source of discrepancy involves data period, model selected, appropriate lag order, and method used to test causality (Ozturk 2010; Payne 2010; Masih and Masih 1998; Narayan and Prasad 2008). Huang, Hwang and Yang (2008) use panel data for 82 countries from 1972 to 2002 within a VAR with Generalized Method of Moment System model to see the effects between energy consumption and GDP. For low income countries, no causality is found. One-way causality is found running from GDP growth to energy consumption for the middle income countries. Negative one-way causality is

found for the high income countries group running from GDP growth to energy consumption. Considering all countries, they find bi-directional causality between energy and GDP. Surprisingly, none of the groups show causality from energy consumption to economic growth, which was seen after considering all countries.

Investment in Economy Including Education

Rebelo (1992) and Barro (1991) develop endogenous growth models for per capita growth. They conclude that their investment ratio (the ratio of investment to the GDP) and per capita growth move together; investments in human capital increases productivity which in turn increases economic growth. Increase in human capital increases the ratio of investment to the GDP. Other endogenous growth models attempt to explain the long-run relationship between production and technological progress (Romer 1990; Grossman and Helpman 1991a, 1991b; Aghion and Howitt 2000). In models developed in the previously mentioned studies, relationships are established between profit maximizing innovative individuals and technological progress. Romer (1990), for example, argues that increasing returns to scale in the production function highlights the non-rivalrous nature of knowledge. He calculates that for a given level of knowledge, doubling the capital and labor doubles the output, while doubling the knowledge for a given level of capital and labor increases the production more than two fold.

Some portion of GDP is invested to increase the skilled labor pool and technology. If investment is too small to keep the capital labor ratio constant then per capita labor ratio will fall because of the decrease in the number of skilled human capital

(Becker 1962). Hamermesh (1986) and Clark, Hofler and Thompson (1988) find that capital and unskilled labor are poor substitutes. In the long-run, an increase of one percent in the US unskilled labor force will decrease the ratio of unskilled labor to skilled wages by 0.5 percent. About half of the return to investment is associated with unskilled labor and rest half goes to the capital and skilled work force.

De Long and Summers (1991) and Jones (1994) criticize the use of investment data on analyzing economic growth. They argue, using cross country data, that investment in machinery are crucial determinants of economic growth, whereas non-machinery investments are not correlated with growth, even if other crucial components of growth, such as college enrollment rates and income levels, are held constant. If only machinery investment, one third of total investment in US, is crucial for economic growth, then focusing on other investment is misleading (Mahadevan and Asafu-Adjaye 2007). They also claim that subsidies in machinery investments will generate growth in the long term.

Studies using data from Organization for Economic Co-operation and Development (OECD) countries conclude there are negative effects on GDP growth as the government spending as a share of total government spending increases. Smith (1975) finds a strong negative effect between government consumption and investment; whereas, the effect of transfer of government funds to the people is small. Using data from 1960 to 1981 for 21 OECD countries, Saunders (1986) finds a strong negative effect of total government expenditures on GDP growth. Cameron (1982) finds a positive relation between government expenditures and GDP growth; he estimates a one percent

decrease in total government expenditures decreases the growth rate of an economy by 0.05 percent. Gould (1983) finds that the relationship between economic growth of a country and total spending ratio (the ratio of government spending to the GDP) for 13 OECD countries is negative using data from 1960-73. Similar to Gould (1983), Korpi (1989) also analyzes data the from OECD countries following the same procedures, but he does not find a relationship between GDP growth and different spending ratios for 18 OECD countries. For Japan, however, transfers of funds to the citizens and total expenditures on social security have positive effects on GDP growth.

Advancements in technology means increases in efficiency of inputs. An increase in technology increases the capital to number of workers ratio. Given this dynamics, there is no growth of wages relative to the number of workers, but wages per worker increase (Huber 1990; Gumport and Chun 1999). Broadly speaking because of increases in human capital and development of technology, in case of developed countries, returns to capital remains constant (Grossman and Helpman 1994). Grossman and Helpman (1994) find a positive relation between educational expenditures and GDP growth. Baumol, Blackman, and Wolff (1989) and Barro (1991) find that increase in educational expenditures by the government would increase total factors of production. These findings are consistent with the belief that educational expenditures are necessary for the formation of human capital for economic growth.

Government policy, investment, and consumption may not have entirely negative effects on the economic rate of growth. Myrdal (1960) stresses that more direct government involvement in the economy will enhance development by reducing social

inequalities, which are detrimental to economic growth. Equalities lead to a waste of human capital as a consequence of poverty and limits the opportunities of low income families to exploit their talents. Landau (1986) finds significant effects of government expenditures in education, government investment, and transfers on GDP growth. Kormendi and Meguire (1990) using the data from 1950 to 1977 for 47 countries find government consumption to government spending ratio has no effect on GDP growth.

Studies have provided conceptual frameworks that to link economic growth and education (Mankiw, Romer and Weil 1992; Mulligan and Sala-i-Martin 2000). Vandenbussche, Aghion and Meghir's (2006), for example, theoretical framework illustrates how education has a positive effect on economic growth through increases in the technological frontier. In addition, empirical studies support a positive relationship between growth and education (Barro 1991; Levine and Renelt 1992; Mankiw, Romer and Weil 1992). Self and Grabowski (2004) find a strong significant causal relation between primary education and economic growth after analyzing data for India from 1966 to 1996; such a relationship is found to be less strong for secondary education and growth. Pereira and St Aubyn (2009) find that at any level of education, more is better and increased education has a positive effect on growth in Portugal. Some studies include the role of education on human capital development and find a positive relationship between growth and education (Fleisher and Chen 1997; Li and Huang 2009; Li and Liu 2011; Wang and Yao 2003). Other studies find there is negative association between education level and economic growth (Benhabib and Spiegel 1994; Islam 1995; Pritchett 2001). Still other studies find an insignificant relationship between education and growth

when attempting to explain the regional growth disparity in China (Chen and Fleisher 1996; Chen and Feng 2000). Fleisher, Li and Zhao (2010) indicate that the marginal product of workers with more than a high school education is larger than for workers with only an elementary school education. They also claim that the return on investment is higher in developed areas of China than less developed areas. Lau (2010) finds primary school education has a positive association with economic growth, while investments in higher levels of education do not trigger economic growth.

Long-run growth models usually depend on exogenous variables including technological progress (Abramovitz 1986; Jones 1995). Examining total patent applications, patents awarded to US universities and total patent awarded to the US entities, Chellaraj, Maskus, and Mattoo (2005) results indicate that both international graduate students and skilled immigrants have a significant and positive impact on patent awards to the US universities and non-universities. They estimate that a 4.7 percent increase in patent applications will occur with a 10 percent increase in the number of foreign graduate students. With the same percent increase in foreign students, university grants will increase by 5.3 percent and non-university by 6.7 percent. Skilled immigrants also contributed to increase patents, but the effect is smaller. Lawrence Summers (1994) warned the US Department of State that a decline in foreign graduate students will jeopardize the quality of research at US universities. Summers' claim is questioned by Borjas (2004). Evidence suggests that productivity growth and efficient resource use are made possible by advancements in technology (Basu, Fernald and Shapiro 2001; Basu, Fernald and Oulton 2004; Gordon 2004a, 2004b).

Technological advancements are driven by the rate of innovation, which has been increasing in years (Berman and Hagan, 2006; Love and Roper, 1999). Investments made in research are the key to success of innovation as measured by the number of patents awarded to US universities and private firms (Kortum 1997; Hall 2004). Among all countries Korea and Singapore rank highest in science and mathematics (Hazelkorn 2011). US students rank lower in science and mathematics than Singapore, Korea and some other countrie's students. The gap between manpower needed for research and education is being filled by international graduates (Gordon and Vegas 2004). Top ranking of US on innovation and extension of the new technology is possible because of the harnessing of highly skilled manpower from other countries (Fagerberg 2004). Chellaraj, Maskus and Mattoo (2008) using the total number of patents awarded in the US and total percentage of foreign graduates conclude that number of foreign graduates has a statistically significant effect on technology advancement, production, and the patenting process.

Romer (1990) notes skilled manpower and rich human capital are key factors in the research sector; they generate the new ideas and principles that enhance technological progress. For these reasons, countries with high human capital and other capital to support innovations experience a higher rate of technological progress and introduction of new products than countries with lower human capital (Grossman and Helpman 1989). Once an idea is converted to a product, a country needs to have ample population to consume and trust on newly developed products and make product viable in the consumer market. Larger populations make it possible for countries to absorb new products and

ideas (Nelson and Phelps 1966). They suggest follower countries tend to have faster capital growth because they catch up more quickly than the leader in innovation to the technological leader.

CHAPTER III

METHODOLOGY AND DATA DESCRIPTION

A multivariate vector error correction model (VECM) is used to investigate both long-run and short-run relationships between GDP, number of immigrants, investment in education by the government at national and at local levels, national hourly wages, and energy consumption. If the series were not cointegrated, a VAR model would have been estimated. VECM models allow the system to be stable in the long-run through an adjustment coefficient.

To avoid spurious regressions and to reduce the possibility of type I and type II errors, Granger and Newbold (1974) recommend the regression of a non-stationary series at both the non-stationary level and at stationary level to capture the maximum available information in the data. Simple regression using non-stationary variables may estimate spurious relationships. One simple method to avoid spuriousness is to include lagged values of both dependent and independent variables. Parameter estimates using such a procedure are consistent and unbiased (Hamilton 1994).

Order of Integration I(d)

The first step is to test for stationarity of the variables using Augmented Dickey-Fuller (ADF) tests (Dickey and Fuller 1979, 1981). Usually stationary is required to analyze the time series data; however, VECM models are an exception. The most common test for stationarity is the Dickey-Fuller (DF) test (Dickey and Fuller 1979, 1981). ADF tests not only test the presence of unit root but also the number of differences necessary to

make the data series stationary. To test for stationarity of a single series, y_t, consider the following equations

$$y_t = \alpha + \rho\, y_{t-1} + \upsilon_t$$

$$y_t - y_{t-1} = \alpha + \rho\, y_{t-1} - y_{t-1} + \upsilon_t$$

$$\Delta y_t = y_{t-1}(1 - \rho) + \upsilon_t$$

(1) $$\Delta y_t = \Upsilon y_{t-1} + \upsilon_t$$

where ρ is autocorrelation coefficient, Υ is equal to 1- ρ, Δ is the difference operator, and υ_t are random residuals with zero mean and constant variances σ_v. The variance of υ_t is assumed to be fixed over time. There are three basic kind of models used in the ADF tests: (1) without constant or deterministic trend; (2) with a constant and without deterministic trend; and (3) with a constant and deterministic time trend variables. In this research an ADF test with constant is used.

The DF tests whether the autoregressive coefficient of lagged variable is different from zero or not.

$H_0 : \Upsilon = 0$ which implies $Ho: \rho = 1$, and

$H_1 : \Upsilon < 0$ which implies $H_1: \rho < 1$

If the DF calculated statistic is greater than the critical values, then the null hypothesis is not rejected. If the test does not reject the null hypothesis, the series are considered non-stationary. If the null hypothesis is rejected, then one concludes the series is stationary. The critical values for the three different basic models differ because the test statistic is not a standard t-distribution. Dickey and Fuller (1979) provide critical values for the test statistic. If the series is non-stationary, the same procedure is applied after first

differencing the non-stationary data. If first differencing makes the series stationary, it is concluded the series is integrated of order 1, I(1). The series is said to be of integrated order, I(d), if differencing the series d times is necessary for the series to become stationary.

The Augmented Dickey Fuller (ADF) test is an extension of the DF test to account for the possibility of autocorrelation of the residual terms. The general model for the ADF test is

(2) $$\Delta y_t = \alpha + \Upsilon y_{t-1} + \sum_{s=1}^{n} \pi_s \Delta y_{t-s} + \upsilon_t$$

where the parameters are as previously defined, π_s is autoregressive coefficient of the differenced series. The term n is selected such that there is no autocorrelation in the differenced series. The number of lagged values will be determined using information Schwarz (SIC) and Hannan and Quinn (HQ) information criteria.

VAR Lag Selection

Identification of the appropriate lag length is important in developing VECM model. An unrestricted vector autoregressive (VAR) model of order p, VAR (p), includes P lags of each variable in the system. If the lag length differs from "true" lag length estimates are inconsistent (Braun and Mittnik 1993). Lütkepohl (1993) claims that under fitting lag length produces auto-correlated errors; whereas, over fitting the model increases the mean square forecast error. When developing a VAR model lag selection goal is to find the appropriate model such that the estimated parameters are consistent and the model has white noise residuals. The most common other criteria of lag selection that scientists use are Akaike Information Criteria (AIC) and Final Prediction Error (FPE). Here, SIC

and HQ methods are used to select the VAR lag length. These criteria have some common features and selection criteria are the same. The inclusion of additional parameters in model reduces the sum of squared residuals (SSR) which is desirable. Increases in the number of parameters, however, increases the penalty term in the information criteria. The aim is to select the model or appropriate lag length with smallest information criteria value. Different information criteria may provide different optimal lag lengths. The lag length that minimizes loss function yields the residuals that are closest to white noise residuals. Lütkepohl (2007) shows for a multivariate VAR with k variables, T observations, a constant term, and lag length p, the information criteria are

(3) $$HQ(p) = Ln\,|\Sigma(p)| + (K+pk^2)\frac{2\ln(\ln(T))}{T}$$

(4) $$SIC(p) = Ln\,|\Sigma(p)| + (K+pk^2)\frac{\ln(T)}{T}$$

where $|\Sigma(p)|$ is determinant of variance covariance matrix of estimated residuals and Ln in the natural logarithm.

Cointegration

The idea of cointegration was first set forth by Granger (1981, 1986) and expanded by Engle and Granger (1987) and Johansen (1988). Cointegration is possible between two or more I(d) series, generally d = 1. Cointegrated series are series that in the short-run deviate from each other, but in the long-run the series do not drift from each other. This is referred as a long-run relationship between non-stationary series. If y_t and x_t are two

non-stationary, I(1), series then if there exists a linear combination of those series such that the estimated residuals are stationary, then the two series are said to be cointegrated

(5) $$u_t = y_t - \beta_0 - \beta_1 x_t$$

where u_t is I(0). Cointegration implies that x_t and y_t share a common stochastic trend. Cointegration of multivariate series exists when for the vector Y which consists of k series that are integrated of order d, there exists at least one linear combination of variables such that

(6) $$\beta' Y_t = Z_{i,t} \qquad Z_{i,t} \sim I(0)$$

where β' vector is the cointegration matrix which consists of rows of cointegration vectors and Z_{it} is residuals after estimating cointegrating vector.

The vector autoregressive (VAR) representation of the multivariate equation is

(7) $$Y_t = \sum_{j=1}^{p} \Gamma_j Y_{t-j} + U_t$$

where Y_t and Y_{t-j} are vectors of endogenous variables and contains the group of stationary series of dimension k×1 and U_t is vector of white noises of k×1 dimension. The error correction model can be derived from the vector auto regression. Its general form is given as

(8) $$\Delta Y_t = \Pi Y_{t-1} + \sum_{j=1}^{p-1} \Gamma_j \Delta Y_{t-j} + U_t$$

where, $$\Gamma_j = -\sum_{i=j+1}^{p} \Gamma_i \qquad j=1, 2, 3\ldots..p-1 \text{ and}$$

$$\Pi = -(I - \Gamma_1 - \cdots \Gamma_p)$$

where Π = αβ', where β' is the matrix of cointegration vectors and α holds the matrix of responses of each series to perturbations in $\Gamma' Y_{t-1}$, Y_t contains the vector of k series, and Γ_j is vector of estimated coefficient of lagged values of independent variables.

The number of linearly independent cointegration vectors is represented by the rank, r. Johansen (1995) discusses two tests to determine the cointegration rank, r. One uses trace statistics for the k variable model. The trace statistic is

(9) $$\mathrm{Tr}(r) = -T\sum_{i=r+1}^{k}\ln(1-\lambda_i)$$

where λ are estimated eigenvalues and i ranges from r+1 to K. The null hypothesis, H_0, is there are at most r positive Eigenvalues and the alternative hypothesis, H_1, is there are more than r positive eigenvalues. If the trace statistics is larger than the critical value, the null hypothesis which is r cointegrating vectors is rejected.

Another test to identify the cointegration is rank test

(10) $$\lambda_{max}(r, r+1) = -T\ln(1-\lambda_{r+1})$$

where λs' are smallest characteristics roots i.e. eigenvalues. If the test statistics are bigger than critical value then the null hypothesis is rejected. Here, the null hypothesis is there are r cointegrating vectors against alternative hypothesis there are r+1 cointegrating vectors. The Eigenvalue (λ_i) measures the correlation between ΔY_t and $\beta' Y_{t-1}$. If $\beta' Y_{t-1}$ is stationary, ΔY_t is first differenced stationary, then there is cointegration between the variables. If $\beta' Y_{t-1}$ are non-stationary then the Eigenvalues will be zero. If there are K non-stationary series and r Eigenvalues are positive with the remaining K-r Eigenvalues being zero, then the model is said to cointegrating of rank r. In this research trace statistics are used to select appropriate rank test.

Impulse Response Function

Impulse response functions (IRF) track changes in each variable with respect to a shock in one of the variables. Equations (11) through (20) and associated discussions are taken

with slight notation change from Kirchgassner, Wolters and Hassler (2012, pages 140-149). Changes in each variable at time t are traced through the system of equations

$$A(L)Y_t = D + U_t$$

$$Y_t = A^{-1}(L)D + A^{-1}(L)U_t$$

(11) $$Y_t = \mu + B(L)U_t$$

$$B(L) = I_k - \sum_{j=1}^{\infty} B_j L^j \text{ , } \mu = A^{-1}(L)D \text{, and}$$

(12) $$Y_t = \mu + U_t - \sum_{j=1}^{\infty} B_j U_{t-j}$$

where L is lag operator of matrix polynomial. The variance covariance matrix, Σ_{pp}, can be decomposed using the lower triangular matrix P:

$$\Sigma pp = PP'$$

$$Y_t = \mu + PP^{-1}U_t - \sum_{j=1}^{\infty} B_j PP^{-1}U_{t-j}.$$

(13) $$Y_t = \mu + PW_t - \sum_{j=1}^{\infty} \psi_j W_{t-j}$$

where, $\psi_j = B_j P$, $W_t = P^{-1}U_t$ and $W_{t-j} = P^{-1}U_{t-j}$

The multivariate Wold representation of the system expresses Y_t as a function of ortogonalized innovations (W_{t-j})

(14) $$Y_t = \mu + \sum_{j=0}^{\infty} \psi_i W_{t-j}$$

which can be written as

(15) $$Y_t = \mu + \psi_0 W_t + \psi_1 W_{t-1} + \psi_2 W_{t-2} + \ldots.$$

$\psi_t's$ are called impulse response sequences where t ranges from zero to infinity. They measure the impact of one variable on other variables on time t_1 caused by a shock of one of the series at time t_0. μ is vector of deterministic forecast from VECM model containing

the error correction coefficient and appropriate lags of the stationary data series calculated using $A^{-1}(L)D$ as in equation 11. $W_{t,}$ are the vectors of residuals U_t multiplied by P, and U_t is the vector of matrix of residuals at time periods t and are correlated with the succeeding and preceding lags of itself. It is not reasonable to investigate the impulse response on based on the correlated variance covariance matrix (Kirchgassner, Wolters, and Hassler 2012).

Forecast Error Variance Decompositions

Forecast error variance decomposition (FEVD) is the process of attributing the source of variation in forecast errors to each series. This variation is decomposed into parts attributed to the innovation of each series in the system. Wold moving average representation of the system (see equation (14)) is

(16) $$\widehat{Y}_t = \mu + \sum_{j=1}^{\infty} \psi_j W_{t-j}$$

where μ is the deterministic forecast from VECM model containing the error correction coefficient and appropriate lags of the stationary data series. The expected value of Y is

(17) $$E[Y_{t+n}] = \mu + \sum_{j=0}^{n-1} \psi_j E[W_{t+n-j}] + \sum_{j=n}^{\infty} \psi_j E\left[W_{t+n-j}\right]$$

A forecast for the Y_t is

(18) $$\widehat{Y}_t(n) = \mu + \sum_{j=n}^{\infty} \psi_j W_{t+n-j}$$

Because $E[W_{t+n-j}]$ for n greater than t is zero, only $E[W_{t+n-j}]$ where n less than t is observable.

Forecast error is calculated by deducting the realized value from the forecast using the estimated model

$$F_t\left(Y_{(t+n)}\right) = Y_{t+n} - \widehat{Y}\,(n)$$

(19) $$= \sum_{j=1}^{n-1} \psi_j W_{t+n-j}$$

Here, $F_t(Y_{(t+n)})$ is the forecast error. For every element, the forecast error can be decomposed into j components, j=1, 2, …, k

$$Y_{j,t+n} - \widehat{Y}_{j,t}(n) = \sum_{j=0}^{n-1}(\psi_{ji}^{i} W_{1,t+n-1}) + \cdots + \sum_{j=0}^{n-1}(\psi_{jk}^{i} W_{k,t+n-j})$$

(20) $$= \sum_{m=1}^{k}[\sum_{j=0}^{n-1}(\psi_{jm}^{i} W_{m,t+n-1})].$$

The forecast variance has different variation for different components of data i.e. series and for different time periods. The division of sources because of different innovations Wm, m=1, 2 …. k.

(21) $$(Y_{j,t+n} - \widehat{Y}_{j,t}(n))^2 = \sum_{m=1}^{k}\sum_{i=0}^{n-1}(\psi_{jm}^{i})^2 .$$

Because variance of individual element in W is white noise and have variance of one and cross correlation between elements is zero (recall from above W_t are orthogonalized using P). Total forecast variance arising in forecast is decomposed into the source that is arising from as follows

(22) $$W_{jm}^{n} = \frac{\sum_{i=0}^{n-1}(\psi_{jm}^{i})^2}{\sum_{m=1}^{k}\sum_{i=0}^{n-1}(\psi_{jm}^{i})^2}$$

where W_{jm}^{n} represent the share of variable j when forecasting variable m at n period ahead.

Directed Acyclic Graphs (DAGs)

DAGs were developed in the computer field by Pearl (1996, 2000), Pearl and Verma (1991) and Spirtes et al. (2001) with contributions from other fields including statisticians, philosophers, and mathematicians. The use of DAGS can be found in

numerous articles, for example, see Bessler and Lee (2002), Morgan and Winship (2007), Bryant, Bessler, and Haigh (2009), and Mjelde and Bessler (2009).

DAGs are graphical representations of non-parametric structural equation models. Each variable is the result of its own parent variables Pa(s) and idiosyncratic error via some arbitrary function

(23) $$s = f_s(\,Pa(s), e_s)$$

where s represents the variable, f_s is some arbitrary function, Pa(s) are the parent variables of s, and e_s is the error term. Variable s is said to be the cause of variable y if setting different values of s leads to different distributions for y; a change in value of s leads to the change in expected value of y (Pearl, 1996).

Variables are said to be ancestors if the variable has direct and indirect causal effect on other variables. If the variable s has direct and immediate cause on another variable y then the variable s is the parent of variable y and y is a child variable of s. If a DAG has the following combination of arrows, where A, B, C, D are variables included in model, A→B→C→D, then variable A is the parent variable of B, B is a child of A and parent of C. Similarly, variables B, C, and D are descendants of A, whereas variables A, B, and C are ancestors of D. If the arrows are A→B←C, then variable B is called a collider variable (Pearl and Verma 1991).

In DAGs there is no simultaneous effect of between variables. In A →B, variable A has causal effect on B and B is the result of A which means the effect of A at time t will be seen on B at t. Effect variables or response variable show the lagged effect of causal variables. If a line connects two variables but an arrow is absent, A — B, the

interpretation is that information flows between variables, but the direction is not detectable with the available resources. The absence of a line and arrow means that there is no association and causality between the variables.

Researcher at Carnegie Mellon University developed a machine learning algorithm, labelled PC algorithm that searches for causal structures present among a set of at least three variables. The result from PC algorithm is used to develop a Bernanke (1986) ordering of the variable for use in calculation the IRFs and FEVD.

Descriptive Data Statistics

Descriptive data statistics calculates the mean, median, variance, coefficient of variance and other properties of data series. As previously stated, variables to be included are national wages in terms of real dollars per hour, US real GDP, real investment in education by the US at the national and local levels, energy consumption, and yearly number of immigrants. Annual data for the years 1964 through 2011 are used. The number of legal immigrants to the US is from US Department of Homeland Security (2012). GDP in billions of chained 2009 dollars is from Department of Commerce: Bureau of Economic Analysis (2013). Investment in education as a percentage of GDP from US Census Bureau (2013) is multiplied with the respective deflated chained 2009 dollar GDP value to obtain the total real government spending on education. Total government spending on education includes all the investment made by federal government, state governments, and local governments. Annual nominal wage rate is retrieved from US Department of Labor Statistics: Bureau of Labor Statistics (2014) and is converted to real 2009 dollars using the Consumer Price Index (US Department of

Labor Statistics 2014). Energy consumption data, is from United States Energy Information Administration (2014) is the total primary energy consumed by residential, commercial, industrial, transportation and electric power sectors in trillion BTUs.

Table 3.1. Descriptive Statistics of Natural Logarithm of Real GDP, Number of Immigrants, Real Investment in Education (IOE), Energy Consumption, and Real Natural Wage Rate

Statistics	Ln(GDP)	Ln (Immigrants)	Ln(IOE)	Ln(energy)	Ln(wage)
Min	8.224	12.585	5.030	10.855	2.797
Max	9.619	14.418	6.836	11.526	2.996
Range	1.395	1.833	1.806	0.671	1.991
Median	9.023	13.338	6.036	11.311	2.880
Mean	9.002	13.387	6.086	11.305	2.883
SE mean	0.062	0.067	0.071	0.025	0.007
Standard Deviation	0.426	0.465	0.493	0.174	0.053
Coeficient of Variation	0.047	0.035	0.081	0.015	0.018

Unit of measurements are immigrants is natural logarithm of total numbers of immigrants, natural logarithm of GDP in billion dollars, natural logarithm of wage rate in dollars per hour, natural logarithm of investment in education in billion dollars, and natural logarithm of energy consumption in trillion BTU.

Two tables of descriptive statistics are presented. In table 3.1, the descriptive statistics are in natural logarithm units. For the further analysis this data is used. For estimation of the VECM, all variables are in natural logarithms to help account for potential heteroskedasticity. Descriptive statistics in natural units are presented in table

3.2. The number of immigrants is in 100,000 people and energy is in 1000 trillion BTU to avoid large numbers in descriptive statistics.

Table 3.2. Descriptive Statistics of US Real GDP, Real Natural Wage Rate, Energy Consumption, Real Investment in Education, and Immigration

Statistics	GDP	Immigrant	IOE	Energy consumption	Wage
Min	3730.497	2.922	152.950	51.814	16.401
Max	15052.372	18.265	931.099	101.317	20.015
Range	11321.88	15.343	778.148	49.502	3.615
Median	8294.693	6.206	418.441	81.783	17.821
Mean	8855.725	7.241	493.304	82.422	17.893
SE.mean	525.647	0.497	33.865	1.961	0.138
Standard Deviation	3641.791	3.443	234.626	1.359	0.955
Coeficient of Variance	0.411	0.475	0.475	0.164	0.053

Unit of measurement of immigrants are 100,000 numbers of immigrants, GDP in billion dollars, real national wage rate in dollars per hour, investment in education in billion dollars, and energy consumption in 1000 trillion BTU

Graphs of the data series in natural logarithms and natural units are presented in Figures 3.1 and 3.2. The graph shows that the data seems to be non-stationary showing upward trend. However, real wage data have different pattern than other data series. The variability of immigrants has more compared to GDP, IOE and energy while all of these has upward trend. Comparing between wage and immigrants, from 1972 to 1991, wage has downward trend but immigrant has upward trend. Since then both series has upward trend and positive association.

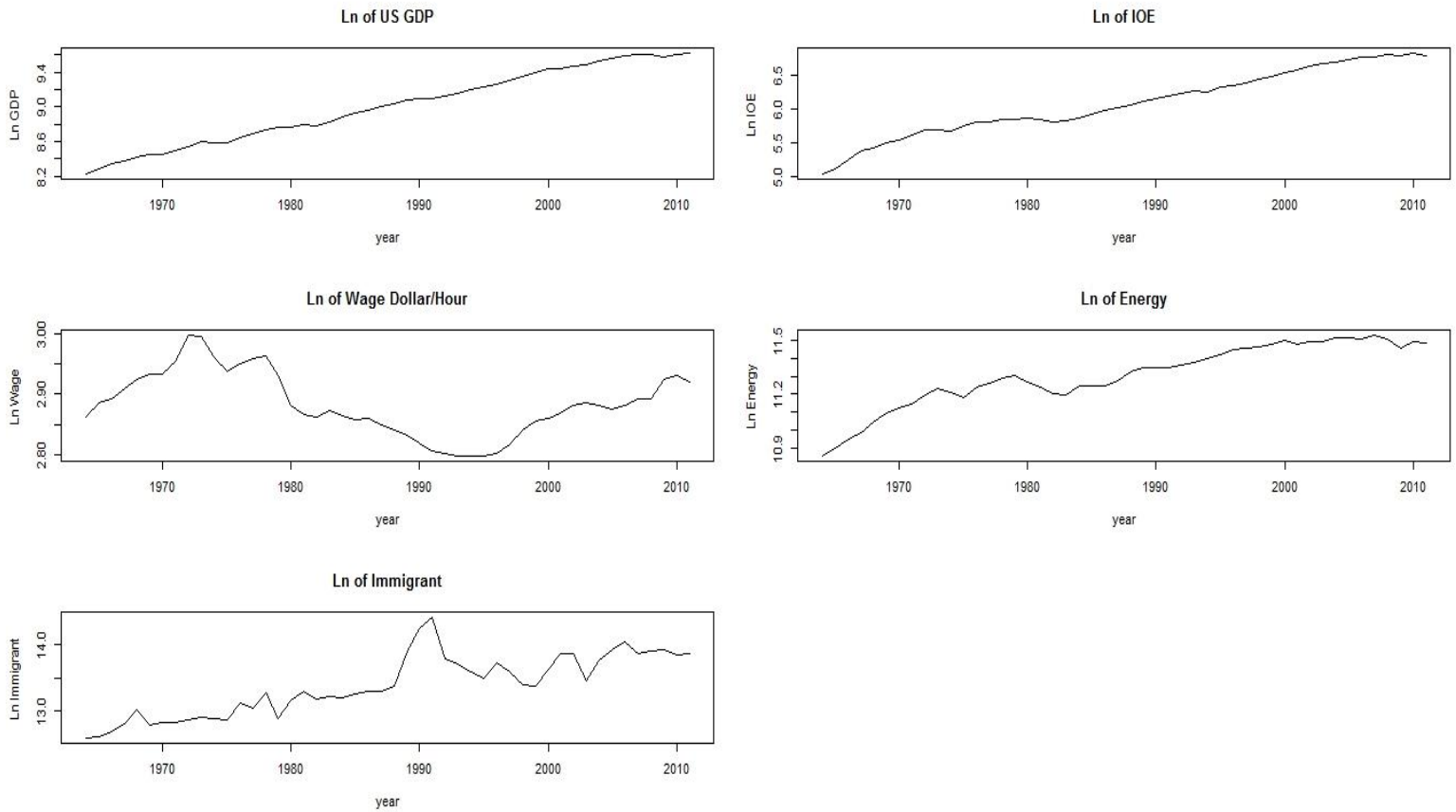

Figure 3.1. Plots of natural logarithm GDP, legal immigrant number, government investment in education, hourly wage, and energy consumption in US

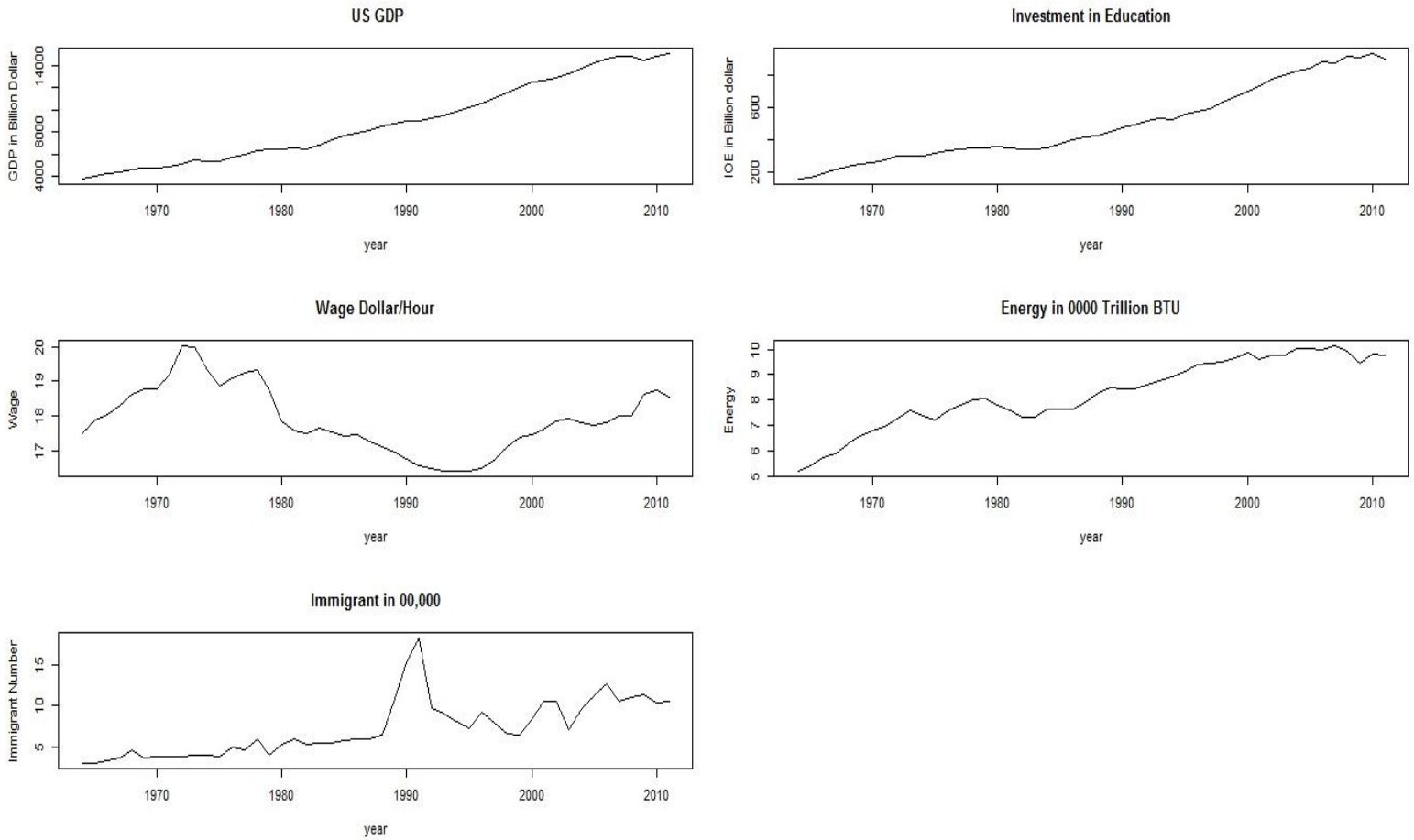

Figure 3.2. Plots of real GDP, yearly legal immigrant's number, government investment in education, hourly wage, and energy consumption in US

CHAPTER IV

RESULTS

The suitability of the use of an error correction models begins with testing the stationarity of the variables. After obtaining the order of integration via ADF tests, appropriate VAR lag length and cointegrating rank are identified. The variance covariance matrix of residuals obtained from the VECM are used to obtain DAGs. IRFs and FEVD are used to identify the dynamic interactions among the variables.

Order of Integration I(d)

ADF tests are used to test the stationarity of the data series. Appropriate number of lags to account for autocorrelations for each series is obtained by minimizing the SIC and HQ information criteria. Considering the number of data observations up to five lags are used for ADF test to calculate the minimum value of the loss criteria. Test statistics from the ADF of for each series associated with the number of lags that minimize the SIC and HQ criteria are presented in table 4.1.

The test is performed including a constant term. In the table, "t-test" column contains the test-statistics and the decision column contains the decision made by comparing with the critical values. The null hypothesis of the test is that the data has unit root; the alternative hypothesis is that the data has root less than one. Rejecting the null hypothesis means one concludes that the data are stationary. Similarly, failing to reject the null hypothesis indicates the data are non-stationary. Results indicate all data series are non-stationary in levels, but all first differences are stationary. From the ADF tests, it is concluded the series are integrated of order one, I(1). For level I(1) of LWAGE

variable t-test is -3.05; the null hypothesis is rejected at the five percent and ten percent level of significance while it is not rejected at one percent level.

Table 4.1. Augmented Dickey-Fuller Tests for Stationarity of Natural Logarithm of GDP, Investment in Education, Wage Rate, Energy Consumption and Immigrant Numbers, Annual Data from 1964 to 2011

	Augmented Dickey Fuller Test					
Data series	t-test	Decision	SIC	Lag (k)	H&Q	Lag (k)
			Level I(0)			
LGDP	-0.992	FTR	-7.492	1	-7.570	1
LIOE	-0.832	FTR	-6.888	1	-6.968	1
LWAGE	-1.184	FTR	-8.217	2	-8.320	2
LENERGY	-1.638	FTR	-7.153	1	-7.321	1
LIMM	-1.834	FTR	-2.872	1	-2.950	1
			Level I(1)			
LGDP	-4.823	R	-7.526	1	-7.604	1
LIOE	-3.049	R	-6.890	1	-6.967	1
LWAGE	-4.889	R	-8.296	1	-8.373	1
LENERGY	-4.745	R	-7.103	1	-7.182	1
LIMM	-5.162	R	-2.805	1	-2.890	2

The t-statistics are not standardized t-distributions, the critical values for the test are obtained from Fuller (1976). The critical values for one percent, five percent and ten percent significance level are -3.58, -2.93 and -2.60. 'FTR' means fail to reject the null hypothesis and 'R' denotes reject the null hypothesis.

VECM

Estimating a VECM usually is a two-step procedure. The first step estimates the appropriate lag length for a VAR; whereas, the second involves determining the rank or number of cointegrating vectors. This two-step procedure is used here. A procedure

based on information criteria that jointly determines lag length and cointegration rank is presented after the lag length determination procedure.

Table 4.2. Lag Length Determination for the VECM Model Using SIC and HQ

Model Selection			
Model	Lag Length (K)	SIC	HQ
VAR(1)	1	**-33.671**	-34.446
VAR(2)	2	-33.559	**-34.981**
VAR(3)	3	-32.359	-34.427
VAR(4)	4	-32.246	-34.960
VAR(5)	5	-31.607	-34.968

Schwarz information criteria (table 4.2) is minimized at a lag length of one, VAR(1). The HQ information criteria minimum values occurs at two lags, VAR(2). A lag length two appears appropriate because it gives both a short-run with long-run matrix. A lag length one only produces long-run-matrix, pi matrix. So, it making it difficult to measure short-run effects. As such, a lag length two is assumed to be appropriate.

Table 4.3. Johansen Test of Cointegration for the Model with Lag Length Two for Ranks One Through Five

Rank	Eigen Value	Lambda Max	Trace	Trace-95percent
1	0.703	55.8443	104.919	69.61
2	0.3825	22.1723	49.074	47.71
3	0.3691	21.1906	26.906	29.8
4	0.0829	3.9818	5.712	15.41
5	0.0369	1.7303	1.730	3.84

The Johansen test is used to determine the number of cointegrating vectors for a model assuming two lags (table 4.3). The trace statistics indicate at the five percent significance level, the appropriate rank of the matrix is at least 3. At a rank of three, the trace statistics is 26.906 and the associated critical value is 29.800. The null hypothesis of no cointegration is rejected for ranks one and two as well. From the above two-step procedure, a VECM of lag length two with three cointegrating vectors is assumed to be the appropriate model. The test tells that variables has two common trends and three cointegrating relations.

Table 4.4. SIC and HQ Information Criteria for the VECM including Lags One to Three and Rank One Through Five for Each Lag

		Information Criteria	
Lag Number	Cointegrating Rank	SIC	HQ
1	1	-34.170	-34.416
1	2	**-34.215**	-34.657
1	3	-34.072	-34.661
1	4	-33.953	-34.640
1	5	-33.865	-34.601
2	1	-33.788	-34.658
2	2	-33.731	-34.801
2	3	-33.697	-34.915
2	4	-33.692	**-35.009**
2	5	-33.577	-34.954
3	1	-32.629	-34.140
3	2	-32.497	-34.209
3	3	-32.439	-34.302
3	4	-32.360	-34.325
3	5	-32.256	-34.270

In table 4.4 and figure 4.1 both the SIC and HQ information criteria associated with VECM models of lag length one to three with ranks of one to five are presented. Rank is checked from one because the previous procedure suggests the variables are cointegrated. Smallest values for the information loss metrics are bolded.

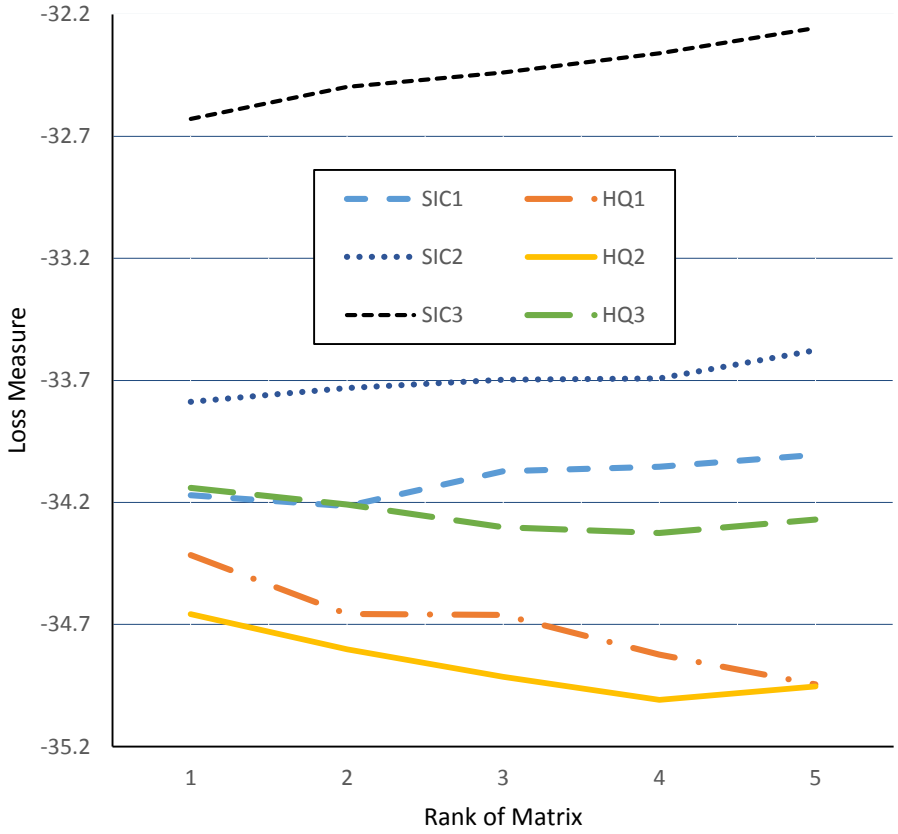

Figure 4.1. SIC and HQ loss functions from VECM models with rank one to five for lags one to three and associated loss metrics

In figure 4.1, SIC1 is Schwarz information criteria for lag one of VAR model, SIC2 for lag two, and SIC3 for lag three. Similarly, HQ1 is for Hannan Quinn loss measure for lag one of VAR model, HQ2 for lag two, and HQ3 for lag three.

As suggested by Wang and Bessler (2005) the information criteria are plotted to provide a visual representation of the procedure's results (Figure 4.1). X-axis has the rank of the cointegrating matrix from one to five, whereas the Y-axis is the loss measure value. SIC is minimized at one lag and rank two. The HQ measure is minimized at two lags and rank four.

Above procedures suggest the series are integrated with either one or two lags. SIC suggests one lag in both procedures, whereas the HQ measure suggests two lags. After considering all the results, a VECM with a lag length of two and rank of four is considered appropriate for further analysis and post estimation procedures. Forecast error variance decompositions and impulse response functions associated with models of lag two and rank of three and lag one and rank two are presented in the Appendix.

Post-Estimation Analysis

Exclusion, Exogeneity, and Stationarity

All the test of exogeneity, exclusion and test of stationarity are performed for the lag two and rank four as selected by the HQ information criteria.

Table 4.5. Tests of Stationarity of the Variables in Levels VECM with Lag Two and Rank Four for Annual Data from 1964 to 2011

Data Series	Chi – Squared Test Statistics	p-value	Decision
LGDP	7.705	0.006	R
LIOE	7.415	0.006	R
LWAGE	3.156	0.076	R
LENERGY	8.839	0.003	R
LIMM	6.849	0.009	R

After estimation of the VECM, stationary of the series conditional to the rank four are again tested. This test is used in conjunction with the ADF test to confirm the nature of the series (table 4.5). The null hypothesis of this stationarity test is that the variable is stationarity in levels. In this test, the degrees of freedom is number of series minus rank which equals one, because five series and a rank of four is assumed. These tests suggest stationarity of all the variables in the system is rejected at the one percentage significance level but LWAGE. Null hypothesis of wage being stationary is accepted at the 10 percent level. The null hypothesis of wage being stationarity is rejected at the eight percentage significance level. This test suggests one of the cointegrating vectors may be because of a variable being stationary. The ADF tests suggest this variable is not stationary in levels.

Table 4.6. Tests of Exclusion of Each Variable from the Cointegrating Space in the VECM Annual Data from 1964 to 2011

Name of Data Series	Decision	Chi- Square test statistics	p-Value
CONSTANT	R	45.761	0.000
LGDP	R	51.544	0.000
LIOE	R	51.065	0.000
LWAGE	R	49.490	0.000
LENERGY	R	26.199	0.000
LIMM	R	26.880	0.000

Exclusion tests examine if a variable is excluded from the cointegrating space that is zero row restriction on beta matrix. The test is asymptotically distributed as χ^2 distribution with r degrees of freedom. If null hypothesis is failed to reject, one concludes the variable is excluded from the long-run relations; the variable is not in the cointegrating space. Given the *p* values in table 4.6, none of the variables are excluded from the system at the one percent level of significance.

Table 4.7. Tests of Weak Exogeneity of Each Variable in the Cointegrating Space

Data Series	Chi – Squared Test Statistics	p–value
LGDP	21.905	0.000
LIOE	23.392	0.000
LWAGE	15.577	0.004
LENERGY	17.081	0.002
LIMM	13.875	0.008

The null hypothesis of the weak exogeneity test is the variables is exogenous, the variable does not respond to the perturbations in cointegrating space. This test statistic is distributed asymptotic as a chi-square distribution with degrees of freedom equal to rank which is four (table 4.7). The null hypothesis means a shock to the variable of interest has no impact on the long-run relationship with the other variables in the system. All null hypotheses are rejected at the one percent significance level. Inference is all variables are endogenous; every variable impacts the others.

Contemporaneous Structure

Contemporaneous cross correlation matrix of the residuals obtained from the estimated VECM model are presented in table 4.8. Based on this cross correlation matrix, contemporaneous causal flow suggested by PC algorithm within tetrad with alpha 0.2 is displayed in figure 4.2. Increasing the penalty discount and significance level helps to identify the direction of undirected edges graphs obtained when using lower penalty discounts and lower alpha level (Ramsey et al. 2010).

Table 4.8. Residual Standard Error and Cross-Correlations Matrix of the Residuals from VECM Model

	DLGDP	DLIOE	DLWAGE	DLENERGY	DLIMM
Standard Error	0.016	0.024	0.010	0.017	0.166
DLGDP	1.000				
DLIOE	0.262	1.000			
DLWAGE	-0.148	0.458	1.000		
DLENERGY	0.700	0.327	-0.300	1.000	
DLIMM	0.051	0.007	-0.079	0.159	1.000

LIMM does not receive any information from any of the other variables and does not pass information to other variables also in contemporaneous time (figure 4.2). The inference is there are no contemporaneous causal relationships among LIMM and the other included variables. LENERGY acts as both an information receiver and provider. It receives information from LGDP and LWAGE and provides information to LIOE. LGDP provides information to LENERGY and does not receive contemporaneous information from any of the other variables in the system. LWAGE is an information provider to both LENERGY and LIOE and does not receive any contemporaneous information from the other variables. LIOE is an information sink; it receives information from LWAGE and LENERGY, but does not provide any contemporaneous information to the other variables.

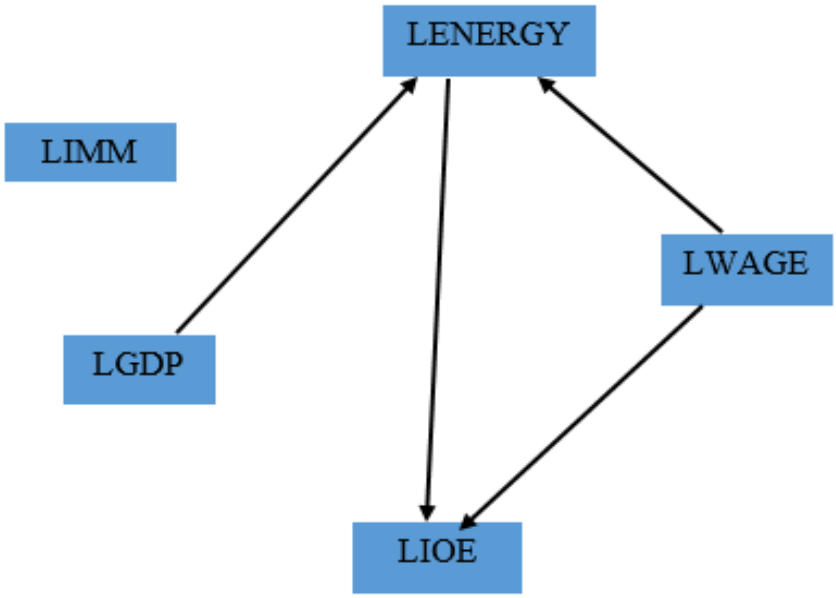

Figure 4.2. Contemporaneous causal relationships of the variables obtained from PC algorithm with alpha 0.2 and depth of -1

Impulse Response Functions

Impulses responses are calculated by applying shocks to one variable at time one and measuring the responses of the variables in the succeeding periods. In figure 4.3, the shock is applied to the variable listed in the column heading and responses for six years (periods) are depicted in graphical form down each column. The quantitative values of the responses are not as important as the direction of response. The responses are normalized by dividing the response with respective standard error of that innovation series making graphs comparable. This normalization provides a better picture of the impulse response functions, is dynamic relationships. The assumption of impulse

responses is the error terms are uncorrelated in contemporaneous time. If the error terms are not independent, then, in calculating the impulse response, setting one error term equal to one and setting other variable error term equal to zero may provide misleading results. As previously noted, Bernanke the contemporaneous structure provided by the DAGs is used in calculating the impulse response functions and forecast error decompositions.

Responses to innovations in the series themselves are presented in the sub graphs on the diagonal in figure 4.3. As expected, an innovation in LGDP leads to an immediate positive response in LGDP. This response has a wavy positive appearance over time. The response is constant for the first two periods, then decreases for the next two periods, and then increases for fifth and sixth time periods. LIOE has a positive response to its own innovation that slowly tapers toward zero. LWAGE responses to own innovations are positive with the response being larger in the second period than the first period. After the second period, the responses tend to slowly decrease. Responses of LENERGY to its own shocks are positive. The responses tend to slightly decrease starting in the fourth period. Finally, the response of LIMM is positive to its own innovations. The responses move towards zero.

All variables response positively to shocks in LGDP but LWAGE. LIOE response is similar for all six years. LWAGE response is zero in first year then the response decreases until year three. After three years, LWAGE responses move towards zero. LENERGY responses to a shock in LGDP are positive tending towards zero overtime. The responses of LIMM to a shock in LGDP slowly increase to the largest

value in year three and then tend towards zero. All variables but LIMM respond positively to innovations in LIOE. As time goes on responses of LGDP as a result of LIMM shock, increases for the first four years and then the responses decreases. LIMM responses negatively to a shock in LWAGE starting in the second year with the responses tending toward zero by year five. All variables in the model responses to innovations in LENERGY are small but LIOE and LENERGY. LIOE responses are positive in first and second year and then taper towards zero.

Innovations in LIMM have negative impacts on all variables except itself. Given the contemporaneous structure, it is expected no variables other than itself response to innovations in LIMM in the year of the shock. The response of LGDP is largest in absolute value in year four after the shock in LIMM. LIOE responses become more negative as time passes. LWAGE responses peak in absolute value in years three and four after the innovation in LIMM, then tend toward zero.

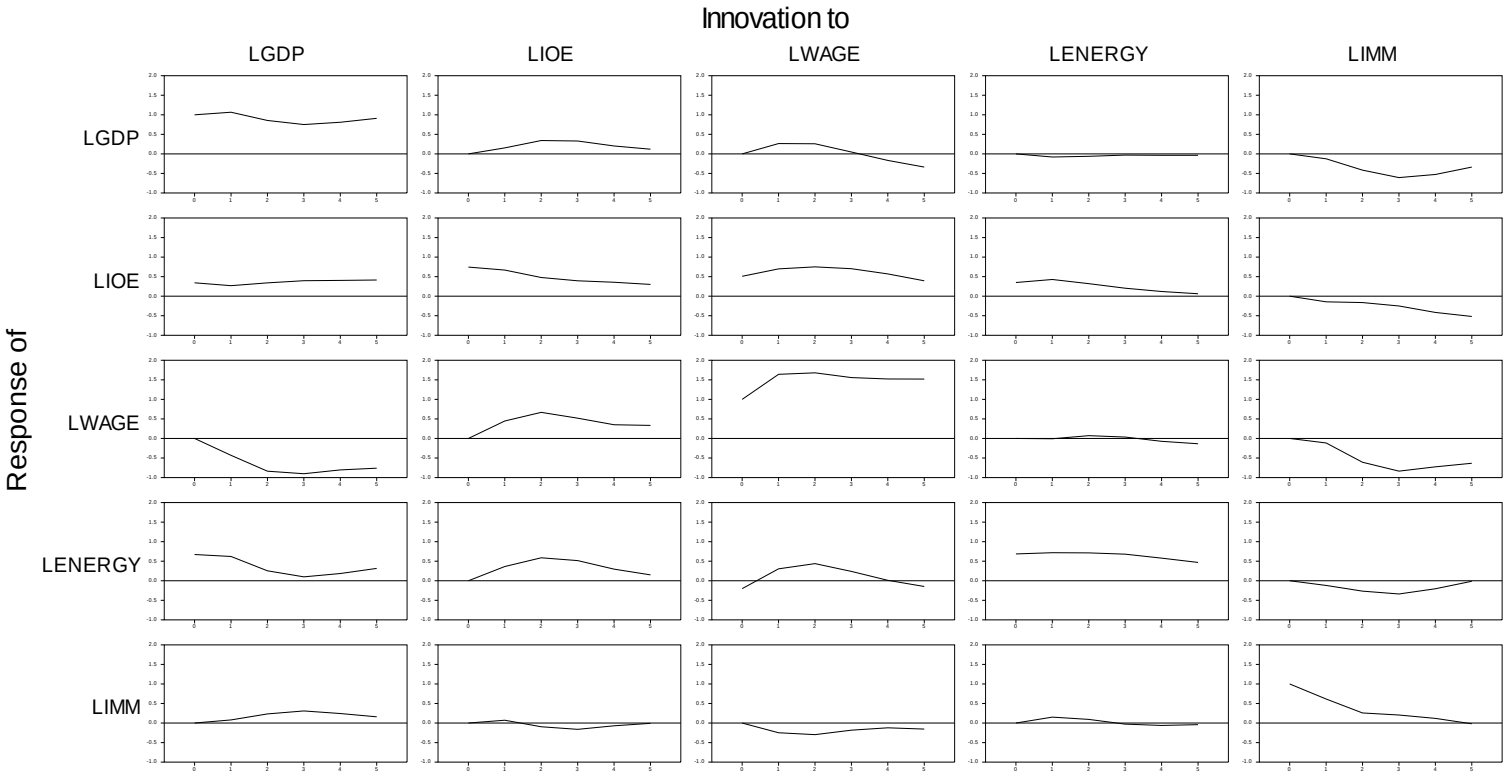

Figure 4.3. Impulse response function; innovation is applied to the column heading variables and responses are shown by the row heading variables

Forecast Error Variance Decompositions

As the time passes, the variances of the forecast errors increase. This is because the source of variance is not only arising from the innovation and variance of the variable of interest, but also the variance of the other variables within the system. In contemporaneous time, for variables, GDP, wage and immigrants, forecast variance is mainly because of the innovation of itself. This also suggests that there is little instantaneous relationships among the variables. And in rest of the variable, share of own variability on forecast error is significant. Variance decompositions measure the importance of the variables in forecasting a variable over time. Decompositions of variances sum up to 100.

At contemporaneous time, variations in the variables are primarily due to the variation of itself except for energy and investment in education (table 4.9). At period one, the total variance of LGDP is attributed entirely to itself; none of the other variables contribute to the variability in one-step ahead forecasts. As, time passes, the variance explained by itself decreases from 100 percent to 76 percent at year 6. LIOE and LENERGY contribute less than five percent to the forecast error in any time period of LGDP. The share of LIMM in explaining the uncertainty of LGDP forecast increases from zero percent to almost 15 percent at year 6. LENERGY explains less than one percentage of total forecast variance in LGDP in all time periods.

Forecast error variance decompositions of LIOE depend on the other variables for all time periods. LIMM role is larger as time increases. The share of LWAGE on forecast error variance decomposition (FEVD) of LIOE increases to 40 percent at year 6.

LIOE explains 52.6 percent to the forecast error at the first one period forecast. Other variables contributions' at year one are LGDP at 11.1 percent, LWAGE at 24.6 percent, and LENERGY at 11.7 percent. The contribution of LIMM, however, increases from zero percent at year one to 9.7 percent at year six. The contribution of LGDP decreases to 8.3 percent in the second period and then increasing to almost 14 percent at year six. The share of LIOE contribution constantly decreases overtime to 28.0 percent by year 6. The contribution of LWAGE gradually increases to 40.1 percent by year 6. The role of LENERGY decreases gradually to 8.2 percent by year six.

LWAGE is exogenous at year one because of the contemporaneous structure assumed. At all steps, LWAGE contribution to its own forecast error variance is 69 percent or larger. LIMM and LGDP also have this level of exogeneity in the system. LENERGY does not contribute to the predictability of the LWAGE; its share of explaining the variability of LWAGE is less than one percent even after six years. LGDP and LIMM have more of a long-term impact on LWAGE than a short-term influence. LIOE contributes between five and eight percent to the error decomposition of LWAGE in all years after the first year.

For one year ahead forecasts, forecast error variance for LENERGY is primarily explained by itself at 49 percent and LGDP at 47 percent. Wages explain the remaining four percent. The percent LENERGY explains of its own variability is constant over the forecast period at approximately 49 percent. Contributions of LGDP decreases to 20.7 percent by the sixth year. LWAGE explains four percent of the first year's forecast

variability but increases and remains around eight to nine percent of variability in forecast of LENERGY. LIOE and LIMM increase in importance as the forecast step increases.

Finally, forecast error variance in LIMM is primarily because to its own variability for all years ahead. LENERGY and LIOE explain less than three percent even in the sixth year. Contributions of LGDP on LIMM variability increase from zero percent for the first year to 11.7 percent by the sixth year. A similar pattern holds for LWAGE. Its share rises from zero percent in year one step to 10.9 percent in the sixth year.

Table 4.9. Forecast Error Variance Decompositions for LGDP, LIOE, LWAGE, LENERGY, and LIMM for Six Years

Step	Std Error	LGDP	LIOE	LWAGE	LENERGY	LIMM
Decomposition of Variance for Series LGDP						
1	0.016	100.00	0.000	0.000	0.000	0.000
2	0.024	94.845	1.051	3.125	0.280	0.699
3	0.029	85.760	4.212	4.108	0.299	5.622
4	0.033	78.232	5.692	3.185	0.248	12.644
5	0.037	75.846	5.396	3.109	0.224	15.424
6	0.041	76.095	4.726	4.355	0.206	14.618
Decomposition of Variance for Series LIOE						
1	0.025	11.128	52.614	24.603	11.655	0.000
2	0.036	8.364	44.185	33.043	13.473	0.935
3	0.044	9.256	37.235	39.691	12.375	1.444
4	0.049	10.981	32.854	42.856	10.683	2.626
5	0.054	12.470	30.136	42.472	9.267	5.656
6	0.057	13.962	28.078	40.050	8.211	9.699
Decomposition of Variance for Series LWAGE						
1	0.010	0.000	0.000	100.00	0.000	0.000
2	0.020	4.551	4.887	90.236	0.002	0.324
3	0.029	10.521	7.676	77.198	0.063	4.541
4	0.035	13.464	7.258	70.677	0.052	8.550
5	0.042	14.443	6.399	69.201	0.074	9.884
6	0.045	14.859	5.855	68.909	0.155	10.216
Decomposition of Variance for Series LENERGY						
1	0.016	46.791	0.000	4.200	49.010	0.000
2	0.024	39.729	6.320	6.349	46.916	0.686
3	0.030	27.427	14.546	9.920	45.518	2.589
4	0.034	21.717	17.717	9.132	46.682	4.752
5	0.036	20.135	17.718	8.161	48.844	5.141
6	0.037	20.663	16.889	8.000	49.674	4.775
Decomposition of Variance for Series LIMM						
1	0.166	0.000	0.000	0.000	0.000	100.000
2	0.202	0.423	0.349	4.201	1.549	93.477
3	0.217	3.563	0.837	8.832	1.862	84.906
4	0.229	8.214	2.118	9.692	1.711	78.266
5	0.234	10.786	2.271	9.965	1.824	75.155
6	0.237	11.740	2.218	10.881	1.860	73.301

CHAPTER V

CONCLUSIONS AND DISCUSSION

Studies attempting to find relationships between immigration and the US economy have found conflicting results. In the short-run, immigrants are more likely to require assistance from the government, but their long-run impact depends on the skill and education level of immigrants (Shea and Woodfield 1996). Other studies also indicate that immigrants may be harmful to the economy (Briggs and More 1994; Dustman and Preston 2006; Aydemir and Borjas 2007). Still some studies claim that immigrants are helpful to the economy (Mines and Martin 1984; Girma and Yu 2002; Rauch 2001).

The objective of this study is to identify the effect of immigration on the US economy through establishing dynamic relationships between selected economic variables and immigration. To investigate the dynamic relationships among US GDP and number of immigrants other selected variables used in research are total investment in education, national wage level and total energy consumption. Estimated parameters from a vector error correction model provide the basis for the analysis of dynamic relationships among the variables through directed acyclical graphs, impulse response functions, and forecast error variance decompositions. Immigrants can contribute in US economy via different ways. First, they are source of individuals for the labor force. Labor is one of the main factors of production. Increasing supply of a factor helps to increase the total domestic output. Second, investment in education will attract more foreign student who are involved in the university and non-university research areas. Research will enhance the existing technology and increase efficiency of factor of

production. Immigrants are not restricted to low wage workers. Third, more immigrants tend to decrease wage because of increased labor supply. There are researches that claim that immigrants increase the wage of natives and other claim immigrants are negatively related with immigrants' wage.

This study finds that the all variables in system are cointegrated with none of the variables being excluded from the cointegration space; in economic terms the variables have long-run associations among them. Any policy passed to influence one variable will have long-term impacts on all the other variables. If, for example, policy makers are considering a policy that has a direct impact on GDP, they should also consider how this policy will influence investment in education, wages, energy consumption, and immigration. Policy makers need to examine polices impacts in this broader prospective. This same argument holds true for policies that affect wages, immigration, energy consumption, and investment in education.

Directd acyclic graph suggests GDP, wages and energy consumption are contemporaneously information providers; whereas, the number of immigrants is, contemporaneously, exogenous to the system. Energy consumption both receives and provides information to the system. This information of directed acyclic graphs provides the idea that GDP and hourly wage has causal impact on the system, in terms of variables that they affect, influenced and information provider for the system. Energy consumption is influenced in contemporaneous time by GDP and wage and whose ultimate response will be seen in investment in investment in education.

Impulse response functions are used to provide the responses over time (six years) of each variable in the system to a shock in one of the variables. All variables except wages respond positively to a shock in GDP in the short term. This result is expected; generally, a growing economy increases funds available to spend on education and energy consumption. Further, a growing economy appears to attract immigrants to the US. Although not new, results suggest policy makers should take these relationships into account as they address problems in the national economy and immigration reform. The impact of shock in GDP on wages, however, is not clear. It may be because increasing GDP increases the number of immigrants that may then decrease the wage level (see discussion below).

Results from impulse response functions bolster support for the idea that immigrants are harmful to the economy, at least in short run because all variables (except itself) respond negatively to a shock in the number of immigrants. This is in line with previous studies such as Briggs and More (1994), Dustman and Preston (2006), Aydemir and Borjas (2006), and Tu (2010) which indicate immigration hurts the US economy. The effect of increasing the number of immigrants appears to be short lived in all variables except investment in education. Once established inside US, the long-run cointegrating test suggests they may contribute to the US economy. Furthermore, more immigrants tend to lower the wage in short-run. This result is similar to the results of Friedberg and Hunt (1995), Friedberg (2001), Borjas (2003), Ottaviano and Peri (2012) and Glitz (2012). This may be because of increased competition in the labor market because of an increase in the labor supply.

Further, results suggest investment in education plays a role in the US economy. Increasing investment in education has a positive effect on GDP, wages, and energy consumption. These impacts appear to short lived, indicating the potential continuing need to invest in education. Increasing investment in education appears to have little impact on the number of immigrants. One possible reason for this lack of relationship in the short run is that most people immigrate to the US for employment opportunities. Shocks to energy consumption have little to no effects on the variables included. This is in line with studies such as Ozturk (2010) and Coers and Sanders (2013) that found small to no relationships between energy consumption and GDP.

Shocks to the wage level have initial positive impacts on GDP and energy consumption. These impacts quickly tend to zero and may even go negative. These results provide some evidence to why both sides maybe correct in the debate over minimum wage / increasing the US wage level. Positive shocks to the wage level have a slight negative effect on the number of immigrants. This may be because natives are more attracted towards working as the wage level increases leaving less jobs available for immigrants.

Forecast error variance decompositions, suggests that the generally majority of the variance is attributed to a series by its own past variance which means uncertainty about the future outcome of one variable has a small effect on the variability of the other variable. As expected, the variance decompositions are similar to impulse response results. So any increase and decrease of a variable will have more effects, in short-run, on its own forecast variability, more than increase or decrease of other variables. But,

share of wage variance on investment in education forecast error is more than variance of itself.

Any polices that shock GDP, positively, have positive impact on investment in education in the short-run. Wage have negative impact from the policies that shocks US economy, GDP. So, policies makers should consider wage alteration because of GDP shock. Similar to GDP response, wage responses similarly with immigrants shock. So any immigrant law and policy will have direct impact on wage and one should analyze the wage effect and wage policy.

Similar patterns are found in immigrant's response on shock of every variable, energy response on investment in education, GDP response on investment, energy response on wage, investment response on energy and GDP response on immigrants, which is negative at first and then moves towards zero. Responses suggests the system responses but then the responses move towards zero after the shock. This suggests the system appears to have self-correcting mechanisms. If one does not consider policy for variables that will come back to normal after one period shock but the question will be whether one can wait till the variables recovers to normal by itself or not. If the time period is too long to recover and effect is unacceptable then one should consider short term policies that makes response variable less responsive to the innovation on other variable without affecting other variables.

Long term, may be permanent looking at the pattern of impulse response graph for six years, response is found in GDP on response of itself, investment response on GDP, wage effect on itself shock, energy on its own shock. So, any policies that affect

on its own will have permanent shock. One time shock will remain for the longer period. Increase in GDP will have long term effect on investment in education.

Broadly speaking, GDP, investment in education, immigrants, energy and wage are related in both the short and long run with potentially differing relationships. Any policies towards one variable will impact the other variables in both the short and long run. When considering policy to influence a specific variable, policy makers should consider the potential impacts on the other variables.

Limitations and Further Research

Data selected for analysis are macroeconomic variables whose changes are influenced by a myriad of factors. The effect of one variable on another may not be experienced correctly if influenced by a variable that is omitted. Use of a dynamic model such as a VECM, however, limits the number of variables that can be included because of the curse of dimensionality. One limitation of the present study is the limited number of variables. Methodologies to overcome this curse are an avenue of further study. Annual data are used; use of a shorter time step may provide further insights.

The number of immigrants to the US included in the model is the number of legal immigrants as defined by the Department of Homeland Security. This number is not broken down by skill levels. Immigrants of varying skills may not contribute at the same level to the economy. Labor efficiency of the different skilled groups will be different. Skilled immigrants may have more of a contribution than unskilled immigrants. Dividing the number of immigrants based on skill level may help determine immigrants influence on the US economy. Because of limitations on data availability, contribution of

immigrants based on their skill level was not possible. Another dimension of immigration is illegal immigrants who contribute to the economy. Many illegal immigrants in the workforce are working in agriculture and construction sectors. Porter (2005) claims that illegal immigrants are adding billions of dollar in social security fund. Inclusion of illegal immigrates in the model may provide a better picture about the overall contribution immigration has to the US economy. Inclusion of indicators of social welfare absorbed by immigrants would allow for one to examine a more complete picture of the role immigrants play in US society.

Wage was deflated by the consumer price index. A better deflator, consistent with deflating GDP, would be the GDP deflator. Use of different deflator may be influencing the results.

Inclusion of changes in policy and technology may provide a fuller picture of how immigration is currently influencing the US economy. Including variables representing major policies such as the Immigration Reform and Control Act of 1986 and the numerous policies enacted after 9/11 may be fruitful. Further, technological advances increase the productivity of factors of production including labor and capital. Including variables which attempt to capture the impacts of policy and technology are another avenue of further research. Immigration and technology may have synergistic effects.

Consumption, imports and exports to the US may also be important in economic growth. Identifying the role immigrants' play on domestic consumption, in general, and in a particular sector, in specific, may provide a better picture of immigrant's effects on the economy. Similar limitations and further research are necessary to determine a fuller

image of immigration's effect on wages. Combining all immigrants into one category and measuring average national wage makes does not allow one to identify the role immigrants play in a particular sector. Separating the effects by sector would help policy makers address the inflow of immigrants in particular categories taking to account wages of natives. Immigrants' contribution, positive or negative, might also differ by geographic area. Further analysis examine the effects of immigrants in different areas where there are different concentrations of immigrants with differing skill sets.

Results suggest that energy consumption depends on GDP but GDP is almost independent of energy consumption. Other studies such as Soytas and Sari (2003), Huang, Hwang and Yang (2008), Yang (2000), and Glasure and Lee (1998) also suggest this relationship. Studies investigating the role of energy and economic growth to identify why this relationship occurs and identify the new players of GDP growth other than energy are necessary. Another interesting finding is that increase in GDP lower the wage level. This opens new avenue for the labor economist to research and identify the cause of negative impact on wages.

The above discussion provides numerous topics and methodologies to further investigate the role of immigration on the economy. Availability of data will be a driving factor of the ability to include additional variables in model along with the curse of dimensionality.

REFERENCES

Abramovitz, M. 1986. "Catching Up, Forging Ahead, and Falling Behind." *The Journal of Economic History* 46:385-406.

Acemoglu, D. 2002. "Directed Technical Change." *The Review of Economic Studies* 69:781-809.

Aghion, P., and P. Howitt. 2000. *On the Macroeconomic Effects of Major Technological Change*. Eds. Encaoua, D., Hall, B.H., Laisney, F., Mairesse, J.. New York: Springer, pp. 31-53.

Akarca, A.T., and T.V. Long II. 1979. "Energy and Employment: A Time-Series Analysis of the Causal Relationship." *Resources and Energy* 2:151-162.

Altonji, J.G., and D. Card.1991. "*The Effects of Immigration on the Labor Market Outcomes of Less-Skilled Natives.*" Eds. Abowd, J.M., Freeman, R.B.. Princeton, N.J.: Industiral Relations Section. Princeton University.pp. 201-234.

Ang, J.B. 2007. "CO2 Emissions, Energy Consumption, and Output in France." *Energy Policy* 35:4772-4778.

Apergis, N., and J.E. Payne. 2009. "CO2 Emissions, Energy Usage, and Output in Central America." *Energy Policy* 37:3282-3286.

Asafu-Adjaye, J. 2000. "The Relationship Between Energy Consumption, Energy Prices and Economic Growth: Time Series Evidence from Asian Developing Countries." *Energy Economics* 22:615-625.

Aslan, A., N. Apergis, and S. Yildirim. 2013. "Causality Between Energy Consumption and GDP in the US: Evidence From Wavelet Analysis." *Frontiers in Energy* 8:1-8.

Autor, D.H., L.F. Katz, and M.S. Kearney. 2008. "Trends in US Wage Inequality: Revising the Revisionists." *The Review of Economics and Statistics* 90:300-323.

Aydemir, A., and G.J. Borjas. 2006. "A Comparative Analysis of the Labor Market Impact of International Migration: Canada, Mexico, and the United States." Working Paper, National Bureau of Economic Research, Cambridge, MA. [Web Page] Retrieved from http://www.nber.org/papers/w12327 (accessed May 23, 2014).

Barro, R.J. 1991. "Economic Growth in a Cross Section of Countries. "*The Quarterly Journal of Economics* 106:407-443.

Bartel, A.P. 1989. "Where Do the New US Immigrants Live?" *Journal of Labor Economics* 7:371-391.

Basu, S., J.G. Fernald, and N. Oulton. 2004. "The Case of the Missing Productivity Growth, or Does Information Technology Explain Why Productivity Accelerated in the United States but Not in the United Kingdom?" *NBER Macroeconomics Annual 2003, Volume 18.* The MIT Press, pp. 9-82.

Basu, S., J.G. Fernald, and M.D. Shapiro. 2001. "Productivity Growth in the 1990s: Technology, Utilization, or Adjustment?". *Carnegie-Rochester Conference Series on Public Policy* 55:117-165.

Baumol, W.J., S.A.B. Blackman, and E.N. Wolff. 1989. *Productivity and American Leadership: The Long View* Cambridge, MA: MIT Press.

Becker, G.S. 1962. "Investment in Human Capital: A Theoretical Analysis." *The Journal of Political Economy* 70: 9-49.

Belloumi, M. 2009. "Energy Consumption and GDP in Tunisia: Cointegration and Causality Analysis." *Energy Policy* 37:2745-2753.

Benhabib, J., and M.M. Spiegel. 1994. "The Role of Human Capital in Economic Development Evidence from Aggregate Cross-Country Data." *Journal of Monetary Economics* 34:143-173.

Berman, S.J., and J. Hagan. 2006. "How Technology-Driven Business Strategy Can Spur Innovation and Growth." *Strategy & Leadership* 34:28-34.

Bernanke, B.S. 1986. "Alternative Explanations of the Money-Income Correlation." In *Carnegie-Rochester Conference Series on Public Policy* 25:49-99.

Bessler, D.A., and S. Lee. 2002. "Money and Prices: US Data 1869–1914 (A Study with Directed Graphs)." *Empirical Economics* 27:427-446.

Blackburn, M.L., D.E. Bloom, and R.B. Freeman.1989. "The Declining Economic Position of Less-Skilled American Males." Working Paper, National Bureau of Economic Research, Washington DC. [Web Page] Retrieved from http://www.nber.org/papers/w3186 (accessed May 12, 2014).

Blum, B.S. 2008. "Trade, Technology, and the Rise of the Service Sector: The Effects on US Wage Inequality." *Journal of international Economics* 74:441-458.

Borjas, G.J. 1994. "The Economics of Immigration." *Journal of Economic Literature* 32:1667-1717.

…..... 1995. "The Internationalization of the US Labor Market and the Wage Structure." [Web Page] Retrieved from http://data.newyorkfed.org/research/epr/95v01n1/9501borj.pdf (accessed Feb 14, 2014).

……. 1999. "The Economic Analysis of Immigration." *Handbook of Labor Economics* 3:1697-1760.

……. 2001. *Heaven's Door: Immigration Policy and the American Economy*. Princeton, N.J.:Princeton University Press.

……. 2003. "The Labor Demand Curve is Downward Sloping: Reexamining the Impact of Immigration on the Labor Market." *The Quarterly Journal of Economics* 118:1335-1374.

……. 2004 "Do Foreign Students Crowd out Native Students from Graduate Programs?". Working paper, National Bureau of Economic Research, Washington DC. [Web Page] Retrieved from http://www.nber.org/papers/w10349 (accessed Jan 17, 2014).

Borjas, G.J., R.B. Freeman, and L.F. Katz. 1992. "On the Labor Market Effects of Immigration and Trade." *Immigration and the Workforce: Economic Consequences for the United States and Source Areas.* University of Chicago Press: 213-244. [Web Page] Retrieved from http://www.nber.org/chapters/c6910.pdf (accessed March 09, 2014).

……. 1996. "Searching for the Effect of Immigration on the Labor Market. " *American Economic Review* 86:246-251.

Borjas, G.J., R.B. Freeman, L.F. Katz, J. DiNardo, and J.M. Abowd. 1997. "How Much Do Immigration and Trade Affect Labor Market Outcomes?" *Brookings Papers on Economic Activity*:1-90.

Borjas, G.J., J. Grogger, and G.H. Hanson. 2010. "Immigration and the Economic Status of African-American Men." *Economica* 77:255-282.

Braun, P.A., and S. Mittnik. 1993. "Misspecifications in Vector Autoregressions and Their Effects on Impulse Responses and Variance Decompositions." *Journal of Econometrics* 59:319-341.

Briggs, V.M., and S. Moore. 1994. "Still an Open Door? US Immigration Policy and the American Economy." [Web Page] Retrieved from http://www.popline.org/node/297150 (accessed Jan 07, 2014).

Bryant, H.L., D.A. Bessler, and M.S. Haigh. 2006. "Causality in Futures Markets." *Journal of Futures Markets* 26:1039-1057.

Butcher, K.F., and D.E. Card. 1991. "*Immigration and Wages: Evidence From the 1980s*." *The American Economic Review* 81:292-296.

Cameron, D.R. 1982. "On the Limits of the Public Economy." *The Annals of the American Academy of Political and Social Science* 459:46-62.

Card, D. 1989. "The Impact of the Mariel Boatlift on the Miami Labor Market." *Industrials and Labor Relations Review* 43:245-257.

……. 1996. "The Effect of Unions on the Structure of Wages: A Longitudinal Analysis." *Econometrica: Journal of the Econometric Society* 64:957-979.

……. 2001. "Immigrant Inflows, Native Outflows, and the Local Labor Market Impacts of Higher Immigration." *Journal of Labor Economics* 9:22-64.

……. 2005. "Is the New Immigration Really so Bad?." *The Economic Journal* 115:F300-F323.

……. 2009."Immigration and Inequality." *American Economic Review* 99:1-21.

Card, D., and J.E. DiNardo. 2000. "Do Immigrant Inflows Lead to Native Outflows?" *American Economic Review* 90:360-367.

……. 2002."Skill Biased Technological Change and Rising Wage Inequality: Some Problems and Puzzles." *Journal of Labor Economics* 20:733-783.

Castro, M.J. 2002. "The New Cuban Immigration in Context." Dante B. Fascell North-South Center, University of Miami. [Web Page] Retrieved from http://www.revistainterforum.com/english/pdf_en/58AP.pdf (accessed Dec 22, 2013).

Chellaraj, G., K.E. Maskus, and A. Mattoo. 2005. "The Contribution of Skilled Immigration and International Graduate Students to US Innovation." Working Paper (3588),World Bank Policy Research. [Web Page] Retrieved from http://www-wds.worldbank.org/external/default/WDSContentServer/IW3P/IB/2005/11/14/0

00112742_20051114174928/additional/841401968_2005103190201050.pdf) (accessed March 02, 2014).

……..2008. "The Contribution of International Graduate Students to US Innovation." *Review of International Economics* 16:444-462.

Chen, B., and Y. Feng. 2000. "Determinants of Economic Growth in China: Private Enterprise, Education, and Openness." *China Economic Review* 11:1-15.

Chen, J., and B.M. Fleisher. 1996. "Regional Income Inequality and Economic Growth in China." *Journal of Comparative Economics* 22:141-164.

Cheng, B.S., and T.W. Lai. 1997. "An Investigation of Co-integration and Causality Between Energy Consumption and Economic Activity in Taiwan." *Energy Economics* 19:435-444.

Chiquiar, D., and G.H. Hanson. 2002. "International Migration, Self-selection, and the Distribution of Wages: Evidence from Mexico and the United States." *Journal of Political Economy* 113:239-281.

Citrin, J., D.P. Green, C. Muste, and C. Wong. 1997. "Public Opinion Toward Immigration Reform: The Role of Economic Motivations." *The Journal of Politics* 59:858-881.

Clark, D.P., R. Hofler, and H. Thompson. 1988. "Separability of Capital and Labor in US Manufacturing." *Economics Letters* 26:197-201.

Clemens, M.A., C.E. Montenegro, and L. Pritchett. 2009. "The Place Premium: Wage Differences for Identical Workers Across the US Border." [Web Page] Retrieved from http://dash.harvard.edu/handle/1/4412631 (accessed Feb 21, 2014).

Coers, R., and M. Sanders. 2013. "The Energy-GDP Nexus; Addressing an Old Question with New Methods." *Energy Economics* 36:708-715.

D'Amuri, F., and G. Peri. 2011."Immigration, Jobs and Employment Protection: Evidence from Europe." Working Paper, National Bureau of Economic Research, Washington DC. [Web Page] Retrieved from http://www.nber.org/papers/w17139 (accessed June 01, 2014).

Davin, D. 1999. "Internal Migration in Contemporary China." [Web Page] Retrieved from http://www.popline.org/node/280316 (accessed Feb 22, 2014).

Davis, S.J., and J. Haltiwanger. 1991."Wage Dispersion Between and Within US Manufacturing Plants, 1963-1986." Working Paper, National Bureau of Economic Research, Washington DC. [Web Page] Retrieved from http://www.nber.org/papers/w3722 (accessed Feb 22, 2014).

De Long, J.B., and L.H. Summers. 1991. "Equipment Investment and Economic Growth." *The Quarterly Journal of Economics* 106:445-502.

DeFreitas, G. 1988. "Hispanic Immigration and Labor Market Segmentation." *Industrial Relations* 27:195-214.

Dickey, D.A., and W.A. Fuller. 1979. "Distribution of the Estimators for Autoregressive Time Series with a Unit Root." *Journal of the American Statistical Association* 74:427-431.

……. 1981. "Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root." *Econometrica* 49:1057-1072.

Docquier, F., Ç. Özden, and G. Peri. 2010. "The Wage Effects of Immigration and Emigration." Working Paper, National Bureau of Economic Research, Washington DC. [Web Page] Retrieved from http://www.nber.org/papers/w16646 (accessed Feb 27, 2014).

Dustmann, C., A. Glitz, and T. Frattini. 2008. "The Labour Market Impact of Immigration." *Oxford Review of Economic Policy* 24:477-494.

Dustmann, C., and I. Preston. 2006. "Is Immigration Good or Bad for the Economy? Analysis of Attitudinal Responses." *Research in Labor Economics* 24:3-34.

Engle, R.F., and C.W. Granger. 1987. "Co-integration and Error Correction: Representation, Estimation, and Testing." *Econometrica: Journal of the Econometric Society* 5:251-276.

Erol, U., and E.S. Yu. 1987. "On the Causal Relationship Between Energy and Income for Industrialized Countries." *Journal of Energy and Development* 13:113-122.

Fagerberg, J. 2004. "Innovation: A Guide to the Literature." [Web Page] Retrieved from https://smartech.gatech.edu/handle/1853/43180 (accessed April 02, 2014).

Feenstra, R.C., and G.H. Hanson. 1997. "Foreign Direct Investment and Relative Wages: Evidence from Mexico's Maquiladoras." *Journal of International Economics* 42:371-393.

Filer, R. 1992. "The Effect of Immigrant Arrivals on Migratory Patterns of Native Workers." *Immigration and the Workforce: Economic Consequences for the United States and Source Areas.* University of Chicago Press, pp. 245-270.

Fleisher, B.M., and J. Chen. 1997. "The Coast–Noncoast Income Gap, Productivity, and Regional Economic Policy in China." *Journal of Comparative Economics* 25:220-236.

Fleisher, B., H. Li, and M.Q. Zhao. 2010. "Human Capital, Economic Growth, and Regional Inequality in China." *Journal of Development Economics* 92:215-231.

Frey, W.H. 1995. "Immigration and Internal Migration Flight from US Metropolitan Areas: Toward a New Demographic Balkanisation." *Urban Studies* 32:733-757.

Frey, W.H., and K.L. Liaw. 1998. "Immigrant Concentration and Domestic Migrant Dispersal: Is Movement to Nonometropolitan Areas 'White Flight'?" *The Professional Geographer* 50:215-232.

Friedberg, R.M. 2001. "The Impact of Mass Migration on the Israeli Labor Market." *The Quarterly Journal of Economics* 116:1373-1408.

Friedberg, R.M., and J. Hunt. 1995. "The Impact of Immigrants on Host Country Wages, Employment and Growth." *The Journal of Economic Perspectives* 9:23-44.

Fuller ,W.A. 1976. *Introduction to Statistical Time Series.* New York: John Wiley.

Gallo, M.L. 2002. "Picture This: Immigrant Workers Use Photography for Communication and Change." *Journal of Workplace Learning* 14:49-57.

Gilder, G. 2012. *Wealth and Poverty: A New Edition for the Twenty-First Century*: Regnery Publishing, Incorporated, An Eagle Publishing Company.

Girma, S., and Z. Yu. 2002. "The Link Between Immigration and Trade: Evidence From the United Kingdom." Ed. Snower D., *Weltwirtschaftliches Archiv* 138:115-130.

Glasure, Y.U. 2002. "Energy and National Income in Korea: Further Evidence on the Role of Omitted Variables." *Energy Economics* 24:355-365.

Glitz, A. 2012. "The Labor Market Impact of Immigration: An ARDL Bounds Testing Approach." *Economics Letters* 90:72-76.

Goldin, C., and L.F. Katz. 2007. "Long-Run Changes in the US Wage Structure: Narrowing, Widening, Polarizing." Working Paper, National Bureau of

Economic Research, Washington DC. [Web Page] Retrieved from http://www.nber.org/papers/w13568 (accessed May 15, 2014).

Gordon, R.J. 2004a."Two Centuries of Economic Growth: Europe Chasing the American Frontier." Working Paper, National Bureau of Economic Research, Washington DC. [Web page] Retrieved from http://www.nber.org/papers/w10662 (accessed May 15, 2014).

…….. 2004b."Why was Europe Left at the Station when America's Productivity Locomotive Departed?" Working Paper, National Bureau of Economic Research, Washington DC. [Web page] Retrieved from http://www.nber.org/papers/w10661 (accessed April 07, 2014).

Gordon, N., and E. Vegas. 2004. "Education Finance Equalization, Spending, Teacher Quality and Student Outcomes: The Case of Brazil's FUNDEF." *Education Sector, Human Development Department, Latin America and the Caribbean Region,* World Bank, Washington, DC.

Gould, W.B. 1983. "Union Involvement in Employer Decision-Making: Some Reflections on America and Europe." *Tulane Law Review* 58:1322.

Granger, C.W. 1981. "Some Properties of Time Series Data and Their Use in Econometric Model Specification." *Journal of Econometrics* 16:121-130.

Granger, C.W. 1986. "Developments in the Study of Cointegrated Economic Variables." *Oxford Bulletin of Economics and Statistics* 48:213-228.

Granger, C.W., and P. Newbold. 1974. "Spurious Regressions in Econometrics." *Journal of Econometrics* 2:111-120.

Greenwood, M.J. 1993. "Migration: A Review." *Regional Studies* 27:295-296.

Greenwood, M.J., and G.L. Hunt. 1995. "Economic Effects of Immigrants on Native and Foreign-Born Workers: Complementarity, Substitutability, and Other Channels of Influence." *Southern Economic Journal* 61:1076-1097.

Greenwood, M.J., and J.M. McDowell. 1986. "The Factor Market Consequences of US Immigration." *Journal of Economic Literature* 24:1738-1772.

Grogger, J., and G.H. Hanson. 2011. "Income Maximization and the Selection and Sorting of International Migrants." *Journal of Development Economics* 95:42-57.

Grossman, J.B. 1982. "The Substitutability of Natives and Immigrants in Production." *The Review of Economics and Statistics* 64:596-603.

Grossman, G.M., and E. Helpman. 1989. "Trade, Innovation and Growth." *The American Economic Review* 80:86-91.

…..... 1991a. "Quality Ladders in the Theory of Growth." *The Review of Economic Studies* 58:43-61.

……. 1991b. "Trade, Knowledge Spillovers, and Growth." *European Economic Review* 35:517-526.

……. 1994."Technology and Trade." Working paper, National Bureau of Economic Research, Washington DC. [Web Page] Retrieved from http://www.nber.org/papers/w4926 (accessed May 22, 2014).

Gumport, P.J., and M. Chun. 1999. *Technology and Higher Education: Opportunities and Challenges for the New Era*: National Center for Postsecondary Improvement, School of Education Stanford University.

Hall, B.H. 2004. "Exploring the Patent Explosion." *The Journal of Technology Transfer* 30:35-48.

Hamermesh, D.S. 1986. "The Demand for Workers and Hours and the Effects of Job Security Policies: Theory and Evidence." National Bureau of Economic Research, Cambridge. [Web page] Retrieved from http://www.nber.org/papers/w2056 (accessed April 09, 2014).

Hamermesh, D.S., and J.E. Biddle. 1993."Beauty and the Labor Market." *American Economic Review* 84:1174-1194.

Hamilton, J.D. 1994. *Time Series Analysis*. Princeton N.J.:Princeton University Press.

Harrigan, J. 2000. "International Trade and American Wages in General Equilibrium, 1967-1995." Ed. Feenstra R.C. In *The Impact of International Trade on Wages.* University of Chicago Press, pp. 171-196. [Web Page] Retrieved from http://www.nber.org/papers/w6981 (accessed May 02, 2014).

Harrigan, J., and R. Balaban. 1999."US Wages in General Equilibrium: the Effects of Prices, Technology, and Factor Supplies, 1963-1991." Working Paper, National Bureau of Economic Research, Washington DC. [Web Page] Retrieved from http://www.nber.org/papers/w6981 (accessed on June 02, 2014).

Hatfield, M. 2004. "Vulnerability to Persistent Low Income." *Horizons* 7:19-26.

Hazelkorn, E. 2011. "Rankings and the Reshaping of Higher Education: The Battle for World Wide Excellence." [Web Page] Retrieved from http://arrow.dit.ie/cgi/viewcontent.cgi?article=1010&context=cserbk&sei-redir=1&referer=httppercent3Apercent2Fpercent2Fscholar.google.compercent2Fscholarpercent3Fqpercent3Dhazelkornpercent2B2011percent26btnGpercent3Dpercent26hlpercent3Denpercent26as_sdtpercent3D0percent252C44#search=percent22hazelkornpercent202011percent22 (accessed May 12, 2014).

Heckman, J.J., L. Lochner, and C. Taber. 1998. "Explaining Rising Wage Inequality: Explorations with a Dynamic General Equilibrium Model of Labor Earnings with Heterogeneous Agents." *Review of Economic Dynamics* 1:1-58.

Heckscher, E.F., and B.G. Ohlin. 1991. *Heckscher-Ohlin Trade Theory*. Cambridge, MA:The MIT Press.

Hill, R.C., W.E. Griffiths, and G.C. Lim. 2008. *Principles of Econometrics*. NJ:Wiley Hoboken.

Hondroyiannis, G., S. Lolos, and E. Papapetrou. 2002. "Energy Consumption and Economic Growth: Assessing the Evidence from Greece." *Energy Economics* 24:319-336.

Hsiao, C. 1981. "Autoregressive Modelling and Money-Income Causality Direction." *Journal of Monetary Economics* 7:85-106.

Huang, B. N., M. Hwang, and C. Yang. 2008. "Causal Relationship Between Energy Consumption and GDP Growth Revisited: a Dynamic Panel Data Approach." *Ecological Economics* 67:41-54.

Huber, J. 1990. "Macro-Micro Links in Gender Stratification: 1989 Presidential Address." *American Sociological Review* 55:1-10.

Iredale, R. 2001. "The Migration of Professionals: Theories and Typologies." *International Migration* 39:7-26.

Islam, N. 1995. "Growth Empirics: A Panel Data Approach." *The Quarterly Journal of Economics* 110:1127-1170.

Jaeger, D.A. 1996. "Skill Differences and the Effect of Immigrants on the Wages of Natives." Working Paper, US Bureau of Labor Statistics, Washington DC. [Web Page] Retrieved from http://www.djaeger.org/research/wp/blswp273.pdf (accessed March 28, 2014).

Jandt, F.E. 2012. *An Introduction to Intercultural Communication: Identities in a Global Community*. 4th ed. Thousand Oaks, Calif.: Sage Publications.

Johansen, S. 1988. "Statistical Analysis of Cointegration Vectors." *Journal of Economic Dynamics and Control* 1:231-254.

Johansen, S. 1991. "Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models." *Econometrica: Journal of the Econometric Society* 59:1551-1580.

Johansen, S. 1995. "Likelihood-Based Inference in Cointegrated Vector Autoregressive Models." *OUP Catalogue*. [web Page] Retrieved from http://ideas.repec.org/b/oxp/obooks/9780198774501.html (accessed May 22, 2014).

Johnson, K.R. 1997. "Race, the Immigration Laws, and Domestic Race Relations: A Magic Mirror into the Heart of Darkness." *Indiana Law Journal* 73:1111-1158.

Jokisch, B., and J. Pribilsky. 2002. "The Panic to Leave: Economic Crisis and the 'New Emigration' from Ecuador." *International Migration* 40:75-102.

Jones, C.I. 1994. "Economic Growth and the Relative Price of Capital." *Journal of Monetary Economics* 34:359-382.

……. 1995. "Time Series Tests of Endogenous Growth Models." *The Quarterly Journal of Economics* 110:495-525.

Juhn, C., K.M. Murphy, and B. Pierce. 1993. "Wage Inequality and the Rise in Returns to Skill." *Journal of Political Economy* 101:410-442.

Karanfil, F. 2009. "How Many Times Again will We Examine the Energy-Income Nexus Using a Limited Range of Traditional Econometric Tools?" *Energy Policy* 37:1191-1194.

Katz, L.F., and K.M. Murphy. 1992. "Changes in Relative Wages, 1963–1987: Supply and Demand Factors." *The Quarterly Journal of Economics* 107:35-78.

Kirchgassner, G., J.Wolters, and U. Hassler. 2012. "Introduction to Modern Time Series Analysis." New York. Springer, 2012.

Kormendi, R.C., and P. Meguire. 1990. "Government Debt, Government Spending, and Private Sector Behavior: Reply and Update." *The American Economic Review* 80:604-617.

Korpi, W. 1989. "Power, Politics, and State Autonomy in the Development of Social Citizenship: Social Rights During Sickness in Eighteen OECD Countries Since 1930." *American Sociological Review* 54:309-328.

Kortum, S.S. 1997. "Research, Patenting, and Technological Change." *Econometrica* 65:1389-1419.

Kraft, J., and A. Kraft. 1978. "Relationship Between Energy and GNP." *Journal of Energy Development* 3:2.

Krugman, P.R. 1979. "Increasing Returns, Monopolistic Competition, and International Trade." *Journal of International Economics* 9:469-479.

Krugman, P., and R. Lawrence. 1994. "Trade, Jobs and Wages." *Scientific American* 270:44-49.

Kuznets, S. 1957. "Quantitative Aspects of the Economic Growth of Nations: II. Industrial Distribution of National Product and Labor Force." *Economic Development and Cultural Change* 5:1-111.

LaLonde, R.J., and R.H. Topel. 1991. "Labor Market Adjustments to Increased Immigration." In *Immigration, Trade and the Labor Market.* John M. Abowd and Richard B. Freeman, editors. University of Chicago Press, pp. 167-199.

……. 1992. "The Assimilation of Immigrants in the US Labor Market." In *Immigration and the Workforce:Economic Consequences for the United States and Source Areas.* University of Chicago Press, pp. 67-92.

Landau, D. 1986. "Government and Economic Growth in the Less Developed Countries: an Empirical Study for 1960-1980." *Economic Development and Cultural Change* 35:35-75.

Lau, C.K.M. 2010. "New Evidence About Regional Income Divergence in China." *China Economic Review* 21:293-309.

Lee, C. C. 2005. "Energy Consumption and GDP in Developing Countries: A Cointegrated Panel Analysis." *Energy Economics* 27:415-427.

…….. 2006. "The Causality Relationship Between Energy Consumption and GDP in G-11 Countries Revisited." *Energy Policy* 34:1086-1093.

Lee, C. C., and C.-P. Chang. 2007. "Energy Consumption and GDP Revisited: a Panel Analysis of Developed and Developing Countries." *Energy Economics* 29:1206-1223.

Leibfritz, W., P.S. O'Brien, and J.-C. Dumont. 2003. "Effects of Immigration on Labour Markets and Government Budgets-An Overview." [Web Page] Retrieved from http://papers.ssrn.com/soL3/papers.cfm?abstract_id=385725 (accessed March 12, 2014).

Levine, R., and D. Renelt. 1992. "A Sensitivity Analysis of Cross-Country Growth Regressions." *American Economic Review* 82:942-963.

Li, H., and L. Huang. 2009. "Health, Education, and Economic Growth in China: Empirical Findings and Implications." *China Economic Review* 20:374-387.

Li, K. W., and T. Liu. 2011. "Economic and Productivity Growth Decomposition: An Application to Post-Reform China." *Economic Modelling* 28:366-373.

Longhi, S., P. Nijkamp, and J. Poot. 2008. *Meta-Analysis of Empirical Evidence on the Labour Market Impacts of Immigration*. Working Paper, Population Studies Centre, University of Waikato, New Zealand. [Web Page] Retrieved from http://researchcommons.waikato.ac.nz/handle/10289/804.

Lopez, R., and M. Schiff. 1998. "Migration and the Skill Composition of the Labour Force: the Impact of Trade Liberalization in LDCs." *Canadian Journal of Economics/Revue Canadienne Deconomique* 31:318-336.

Love, J.H., and S. Roper. 1999. "The Determinants of Innovation: R & D, Technology Transfer and Networking Effects." *Review of Industrial Organization* 15:43-64.

Lütkepohl, H. 1993. "Introduction to Multiple Time Series Analysis, 1993." New York: McGraw and Hill Co.

Lütkepohl, H. 2007. *New Introduction to Multiple Time Series Analysis*: New York: McGraw and Hill Co.

Mahadevan, R., and J. Asafu-Adjaye. 2007. "Energy Consumption, Economic Growth and Prices: A Reassessment Using Panel VECM for Developed and Developing Countries." *Energy Policy* 35:2481-2490.

Malthus, T.R. 1888. *An Essay on the Principle of Population: Or a View of a Its Past and Present Effect of Human Hapiness*. London: Turner and Reeves.

Mankiw, N.G., D. Romer, and D.N. Weil. 1992. "A Contribution to the Empirics of Economic Growth." *The Quarterly Journal of Economics* 107:407-437.

Martin, P.L., and A. Richards. 1980. "International Migration of Labor: Boon or Bane." *Monthly Labor Review* 103:4-9.

Masih, A.M., and R. Masih. 1997. "On the Temporal Causal Relationship Between Energy Consumption, Real Income, and Prices: Some New Evidence from Asian-Energy Dependent NICs Based on a Multivariate Cointegration/Vector Error-Correction Approach." *Journal of Policy Modeling* 19:417-440.

…….. 1998. "A Multivariate Cointegrated Modelling Approach in Testing Temporal Causality Between Energy Consumption, Real Income and Prices with an Application to Two Asian LDCs." *Applied Economics* 30:1287-1298.

Massey, D.S. 2008. *New Faces in New Places: The Changing Geography of American Immigration*: New York: Russell Sage Foundation.

McCall, L. 2001. *Complex Inequality: Gender, Class and Race in the New Economy*. NewYork: Routledge.

Meyer, J.B. 2001. "Network Approach Versus Brain Drain: Lessons From the Diaspora." *International Migration* 3:91-110.

Mines, R., and P.L. Martin. 1984. "Immigrant Workers and the California Citrus Industry." *Industrial Relations: A Journal of Economy and Society* 23:139-149.

Mishra, V., R. Smyth, and S. Sharma. 2009. "The Energy-GDP Nexus: Evidence From a Panel of Pacific Island Countries." *Resource and Energy Economics* 31:210-220.

Mjelde, J. W., and D.A., Bessler. 2009. "Market Integration and Among Electricity Markets and Their Major Fuel Source Markets". *Energy Economics* 31:482-491.

Morgan, S.L., and C. Winship. 2007. *Counterfactuals and Causal Inference: Methods and Principles for Social Research*, NewYork:Cambridge University Press.

Mühleisen, M., and K.F. Zimmermann. 1994. "A Panel Analysis of Job Changes and Unemployment." *European Economic Review* 38:793-801.

Mulligan, C.B., and X. Sala-i-Martin. 2000. "Measuring Aggregate Human Capital." *Journal of Economic Growth* 5:215-252.

Murphy, K.M., and F. Welch. 1992. "The Structure of Wages." *The Quarterly Journal of Economics* 107:285-326.

Mussa, M. 1995. "Dynamic Adjustment in the Heckscher-Ohlin-Samuelson Model." *Bertil Ohlin: Critical Assessments* 2:297.

Myrdal, G. 1960. *Beyond the Welfare State*: Duckworth London.

Narayan, P.K., and A. Prasad. 2008. "Electricity Consumption–Real GDP Causality Nexus: Evidence From a Bootstrapped Causality Test for 30 OECD Countries." *Energy Policy* 36:910-918.

Nelson, R.R., and E.S. Phelps. 1966. "Investment in Humans, Technological Diffusion, and Economic Growth." *The American Economic Review* 56:69-75.

Odhiambo, N.M. 2009. "Energy Consumption and Economic Growth Nexus in Tanzania: An ARDL Bounds Testing Approach." *Energy Policy* 37:617-622.

Ottaviano, G., and G. Peri. 2012. "Rethinking the Effects of Immigration on Wages." *Journal of the European Economic Association* 10:152-197

Ozturk, I. 2010. "A Literature Survey on Energy–Growth Nexus." *Energy Policy* 38:340-349.

Paul, S., and R.N. Bhattacharya. 2004. "Causality Between Energy Consumption and Economic Growth in India: A Note on Conflicting Results." *Energy Economics* 26:977-983.

Payne, J.E. 2010. "Survey of the International Evidence on the Causal Relationship Between Energy Consumption and Growth." *Journal of Economic Studies* 37:53-95.

Pearl, J. 1996. "Causation, Action, and Counterfactuals." In *Proceedings of the 6th Conference on Theoretical Aspects of Rationality and Knowledge.* Morgan Kaufmann Publishers Inc., pp. 51-73.

……. 2000. *Causality: Models, Reasoning, and Inference*. NewYork:Cambridge University Press.

Pearl, J., and T. Verma. 1991. *A Theory of Inferred Causation* , California: Morgan Kaufmann San Mateo.

Pereira, J., and M. St Aubyn. 2009. "What Level of Education Matters Most for Growth?: Evidence From Portugal." *Economics of Education Review* 28:67-73.

Peri, G., and C. Sparber. 2009. "Task Specialization, Immigration, and Wages." *American Economic Journal* 1:135-169.

Porter, E. 2005. "Illegal Immigrants are Bolstering Social Security with Billions." *New York Times* 5:A3l.

Pradhan, R.P. 2010. "Energy Consumption-Growth Nexus in SAARC Countries: Using Cointegration and Error Correction Model." *Modern Applied Science* 4:74-90.

Pritchett, L. 2001. "Where Has all the Education Gone?" *The World Bank Economic Review* 15:367-391.

……. 2006. *Let Their People Come: Breaking the Gridlock on International Labor Mobility*: Centre for Global Development. [Web Page] Retrieved form http://deals.textbooks-savings.info/wp-content/uploads/pdfs/Let%20Their%20People%20Come%20Breaking%20the%20Gridlock%20on%20Global%20Labor%20Mobility%20by%20Lant%20Pritchett%20-%20Fabulous.pdf (accessed Feb 27, 2014)..

Ramsey, J,D., S.J. Hanson, C. Hanson, Y.O. Halchenko, R.A. Poldrack, and C. Glymour. 2010. "Six Problems for Causal Inference From FMRI." *Neuroimage* 49:1545-1558.

Rauch, J.E. 2001. "Business and Social Networks in International Trade." *Journal of Economic Literature* 3:1177-1203.

Rebelo, S.T. 1992."Long-run Policy Analysis and Long-run Growth." *Journal of Political Economy* 99:500-521.

Reischauer, R.D. 1989. "Immigration and the Underclass." *The ANNALS of the American Academy of Political and Social Science* 501:120-131.

Romer, P.M. 1990. "Endogenous Technological Change." *Journal of Political Economy* 98:71-102.

Saunders, P. 1986. "Public Expenditure and Economic Performance in OECD Countries." *Journal of Public Policy* 5:1-21.

Self, S., and R. Grabowski. 2004. "Does Education at all Levels Cause Growth? India, a Case Study." *Economics of Education Review* 23:47-55.

Shea, K.L., and A. Woodfield. 1996. " Optimal Immigration, Education and Growth in the Long-run." *Journal of International Economics* 40:495-506.

Simon, J.L. 1999. *The Economic Consequences of Immigration*, Ann Arbor, MI: University of Michigan Press.

Smith, D. 1975. "Public Consumption and Economic Performance." *National Westminster Bank Review,* November 17-30.

Smith, J.P., and B. Edmonston. 1997. *The New Americans: Economic, Demographic, and Fiscal Effects of Immigration*, Atlanta, GA: National Academies Press.

Soytas, U., and R. Sari. 2003. "Energy Consumption and GDP: Causality Relationship in G-7 Countries and Emerging Markets." *Energy Economics* 25:33-37.

Stolper, W., and P.A. Samuelson. 1941. "Protection and Real Wages." *The Review of Economic Studies* 9:58-73.

Spirtes, P., Glymour C., and R. Scheines. 2001. *Causation, Prediction, and Search.* Cambridge, MA: The MIT Press, 2nd edition.

Summers, L.H. 1994. "Our Mexican Challenge." *Law & Policy in International Business* 26:979.

Tu, J. 2010. "The Impact of Immigration on Labour Market Outcomes of Native-Born Canadians." Discussion Paper Series No. 5129. [Web Page] Retrieved from http://ftp.iza.org/dp5129.pdf.

United States Department of Commerce: Bureau of Economic Analysis. 2013. [Web Page] Retreived from http://research.stlouisfed.org/fred2/series/gdpc96 (accessed March 06, 2014).

United States Department of Labor: Bureau of Labor Statistics. 2014. [Web Page] Retrieved from http://research.stlouisfed.org/fred2/series/CPIAUCSL (accessed March 06, 2014).

United Status Department of Labor Statistics: Bureau of Labor Statistics. 2014. [Web Page] Retrieved from http://research.stlouisfed.org/fred2/series/AHETPI (accessed March 06, 2014).

US Department of Commerce. 2013. [Web Page] Retrieved from http://research.stlouisfed.org/fred2/series/GDPC1 (accessed March 19, 2014).

United States Energy Information Administration. 2014. January 2014 Monthly Energy Review: Table 2.1, Energy Consumption by Sector. [Web Page] Retrieved from http://www.eia.gov/totalenergy/data/monthly/dataunits.cfm (accessed March 22, 2014).

Unites States Census Bureau. 2013. [Web Page] Retrieved from http://www.usgovernmentspending.com/download_multi_year (accessed March 25, 2014).

United States Department of Homeland Security. 2012. Migration Policy Institute tabulation of Data: United States Census Bureau 2012, 2011, and 2010 American Community Surveys and 1970, 1990, and 2000 decennial Census data. All other data are from Campbell J. Gibson and Emily Lennon, U.S. Census Bureau, Working Paper No. 29, Historical Census Statistics on the Foreign-Born Population of the United States: 1850 to 1990, U.S. Government Printing Office, Washington, DC, 1999. [Web Page] Retrieved form http://www.dhs.gov/yearbook-immigration-statistics (accessed Feb 22, 2014).

Vandenbussche, J., P. Aghion, and C. Meghir. 2006. "Growth, Distance to Frontier and Composition of Human Capital." *Journal of Economic Growth* 11:97-127.

Wang, Y., and Y. Yao. 2003. "Sources of China's Economic Growth 1952–1999: Incorporating Human Capital Accumulation." *China Economic Review* 14:32-52.

Wang, Z., and D.A. Bessler. 2005. "A Monte Carlo Study on the Selection of Cointegrating Rank Using Information Criteria." *Econometric Theory* 21:593-620.

White, M.J., and L.M. Hunter. 1993. "The Migratory Response of Native-Born Workers to the Presence of Immigrants in the Labor Market." Unpublished, Presented at the Annual Meeting of the Population Association of America Cincinnati Ohio April 1-3 1993.

White, M.J., and Z. Liang. 1998. "The Effect of Immigration on the Internal Migration of the Native-Born Population, 1981–1990." *Population Research and Policy Review* 17:141-166.

Yang, H. Y. 2000. "A Note on the Causal Relationship Between Energy and GDP in Taiwan." *Energy Economics* 2:309-317.

Yu, E.S., and J.Y. Choi. 1985. "Causal Relationship Between Energy and GNP: An International Comparison." *Journal of Energy Development* 10:186-190.

Yu, E.S., and B. K. Hwang. 1984. "The Relationship Between Energy and GNP: Further Results." *Energy Economics* 6:186-190.

Yu, E.S., and J.C. Jin. 1992. "Cointegration Tests of Energy Consumption, Income, and Employment." *Resources and Energy* 14:259-266.

Yuan, C., S. Liu, and N. Xie. 2010. "The Impact on Chinese Economic Growth and Energy Consumption of the Global Financial Crisis: an Input–Output Analysis." *Energy* 35:1805-1812.

Zavodny, M. 1999. "Determinants of Recent Immigrants' Locational Choices." *International Migration Review* 33:1014-1030.

Zhang, X. P., and X. M. Cheng. 2009. "Energy Consumption, Carbon Emissions, and Economic Growth in China." *Ecological Economics* 68:2706-2712.

APPENDIX

The appendix includes tables and figures for alternative models that are not discussed in the text. Forecast error variance decompositions using models with lag two, rank three and lag one rank two are presented in tables A.1 and A.2. Impulse response functions are presented in figures A.1 and A.2. DAGs for the models are also presented.

Table A.1. Forecast Error Variance Decompositions for LGDP LIOE LWAGE LENERGY and LIMM for Six Years Using a VECM Model Lag Two Rank Three

Step	Std.Error	LGDP	LIOE	LWAGE	LENERGY	LIMM
		Decomposition of Variance for Series LGDP				
1	0.016	100	0.000	0.000	0.000	0.000
2	0.024	94.324	0.949	2.727	0.653	1.347
3	0.030	83.377	3.262	3.114	1.066	9.181
4	0.036	72.888	3.716	2.226	1.521	19.654
5	0.041	66.900	2.942	2.930	2.528	24.701
6	0.047	63.422	2.251	5.424	3.933	24.971
		Decomposition of Variance for Series LIOE				
1	0.025	10.156	48.738	26.817	14.289	0.000
2	0.038	6.265	39.328	35.243	18.958	0.207
3	0.048	5.607	32.692	41.785	19.752	0.164
4	0.056	5.685	29.303	45.161	19.715	0.136
5	0.062	6.018	27.887	45.971	19.839	0.285
6	0.066	6.795	27.122	45.28	19.914	0.888
		Decomposition of Variance for Series LWAGE				
1	0.010	0.000	0.000	100	0.000	0.000
2	0.021	4.567	4.871	90.324	0.062	0.177
3	0.031	10.871	7.956	77.688	0.704	2.782
4	0.038	14.189	8.047	72.083	1.141	4.540
5	0.043	15.362	7.517	71.334	1.247	4.542
6	0.048	15.757	7.176	71.631	1.275	4.161
		Decomposition of Variance for Series LENERGY				
1	0.016	40.509	0.000	2.498	56.993	0.000
2	0.025	30.656	6.008	7.449	55.651	0.236
3	0.033	18.407	13.697	12.586	54.851	0.459
4	0.039	13.027	16.570	12.167	57.853	0.383
5	0.044	10.463	16.262	10.632	61.804	0.839
6	0.048	8.989	14.945	9.085	63.675	3.306
		Decomposition of Variance for Series LIMM				
1	0.177	0.000	0.000	0.000	0.000	100
2	0.224	0.015	0.436	2.269	4.293	92.991
3	0.246	0.950	0.369	3.621	7.514	87.546
4	0.263	2.747	0.410	3.366	8.261	85.218
5	0.273	3.723	0.408	3.136	8.874	83.859
6	0.277	4.119	0.557	3.069	9.797	82.459

Table A.2. Forecast Error Variance Decompositions for LGDP LIOE LWAGE LENERGY and LIMM for Six Years Using a VECM Model Lag One Rank Two

Step	Std Error	LGDP	LIOE	LWAGE	LENERGY	LIMM
		Decomposition of Variance for Series LGDP				
1	0.019	100.000	0.000	0.000	0.000	0.000
2	0.027	93.457	0.003	0.690	0.265	5.585
3	0.035	83.816	0.085	1.808	0.499	13.793
4	0.043	74.543	0.446	2.943	0.610	21.457
5	0.052	66.730	1.076	3.928	0.632	27.633
6	0.062	60.429	1.871	4.732	0.608	32.360
		Decomposition of Variance for Series LIOE				
1	0.028	2.260	80.295	15.375	2.070	0.000
2	0.040	2.545	79.774	12.595	1.656	3.428
3	0.048	3.373	75.090	10.108	1.390	10.039
4	0.056	4.671	67.618	7.954	1.192	18.565
5	0.064	6.289	58.694	6.189	1.031	27.798
6	0.073	8.032	49.518	4.814	0.892	36.717
		Decomposition of Variance for Series LWAGE				
1	0.013	0.000	0.000	100	0.000	0.000
2	0.020	6.319	4.501	83.974	1.252	3.954
3	0.026	11.657	8.272	70.347	2.321	7.403
4	0.032	15.036	10.630	61.640	3.009	9.685
5	0.037	17.162	12.087	56.093	3.451	11.207
6	0.041	18.554	13.020	52.401	3.749	12.276
		Decomposition of Variance for Series LENERGY				
1	0.021	49.944	3.606	0.690	45.760	0.000
2	0.028	37.769	12.895	0.404	41.797	7.136
3	0.035	28.118	19.100	0.488	35.562	16.733
4	0.041	21.808	21.793	0.763	30.299	25.337
5	0.047	17.787	22.311	1.119	26.320	32.463
6	0.053	15.186	21.659	1.508	23.309	38.337
		Decomposition of Variance for Series LIMM				
1	0.200	0.000	0.000	0.000	0.000	100
2	0.276	0.005	0.000	0.016	0.006	99.973
3	0.331	0.005	0.002	0.048	0.014	99.932
4	0.375	0.004	0.012	0.093	0.021	99.871
5	0.412	0.008	0.037	0.150	0.026	99.779
6	0.445	0.020	0.080	0.219	0.031	99.650

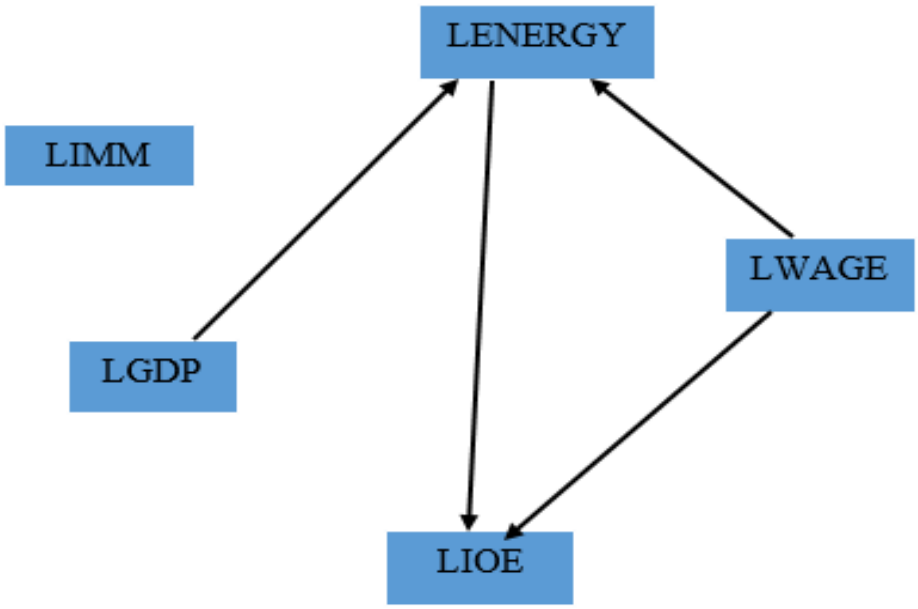

Figure A.1. Contemporaneous causal relationship of the variables obtained from PC algorithm with alpha 0.2 and depth of -1 for a VECM model with lag two and rank three

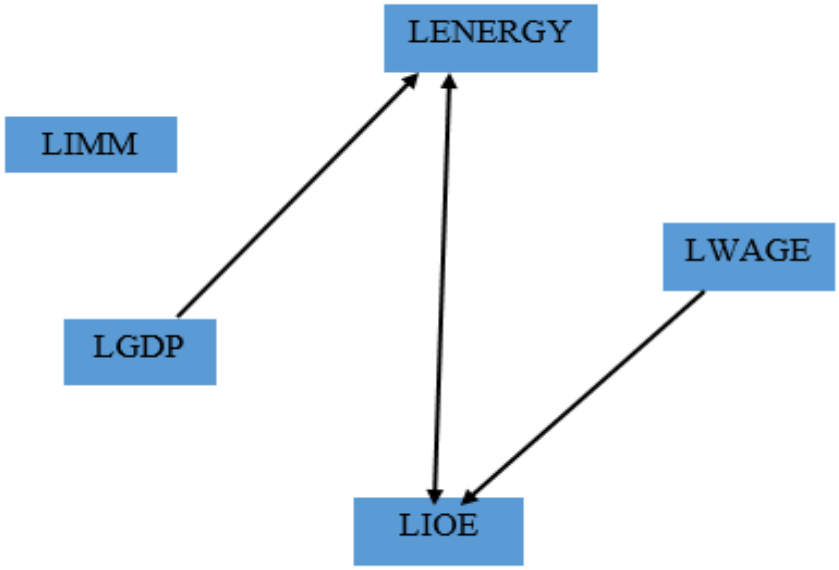

Figure A.2. Contemporaneous causal relationship of the variables obtained from PC algorithm with alpha 0.2 and depth of -1 for a VECM model with lag one and rank two

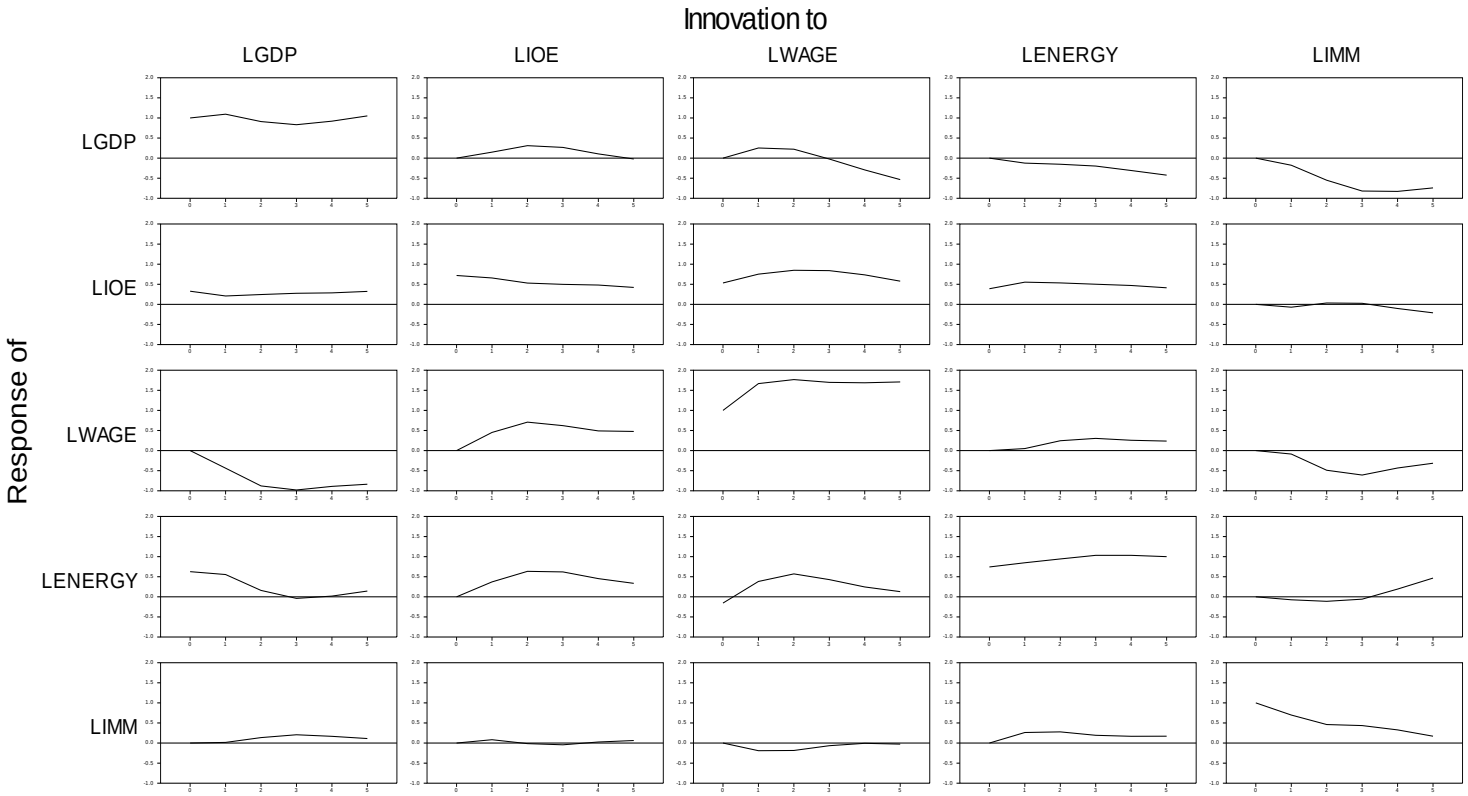

Figure A.3. Impulse response functions innovation is applied to the column heading variables and responses are shown by the row heading variables for a VECM model with lag two and rank three

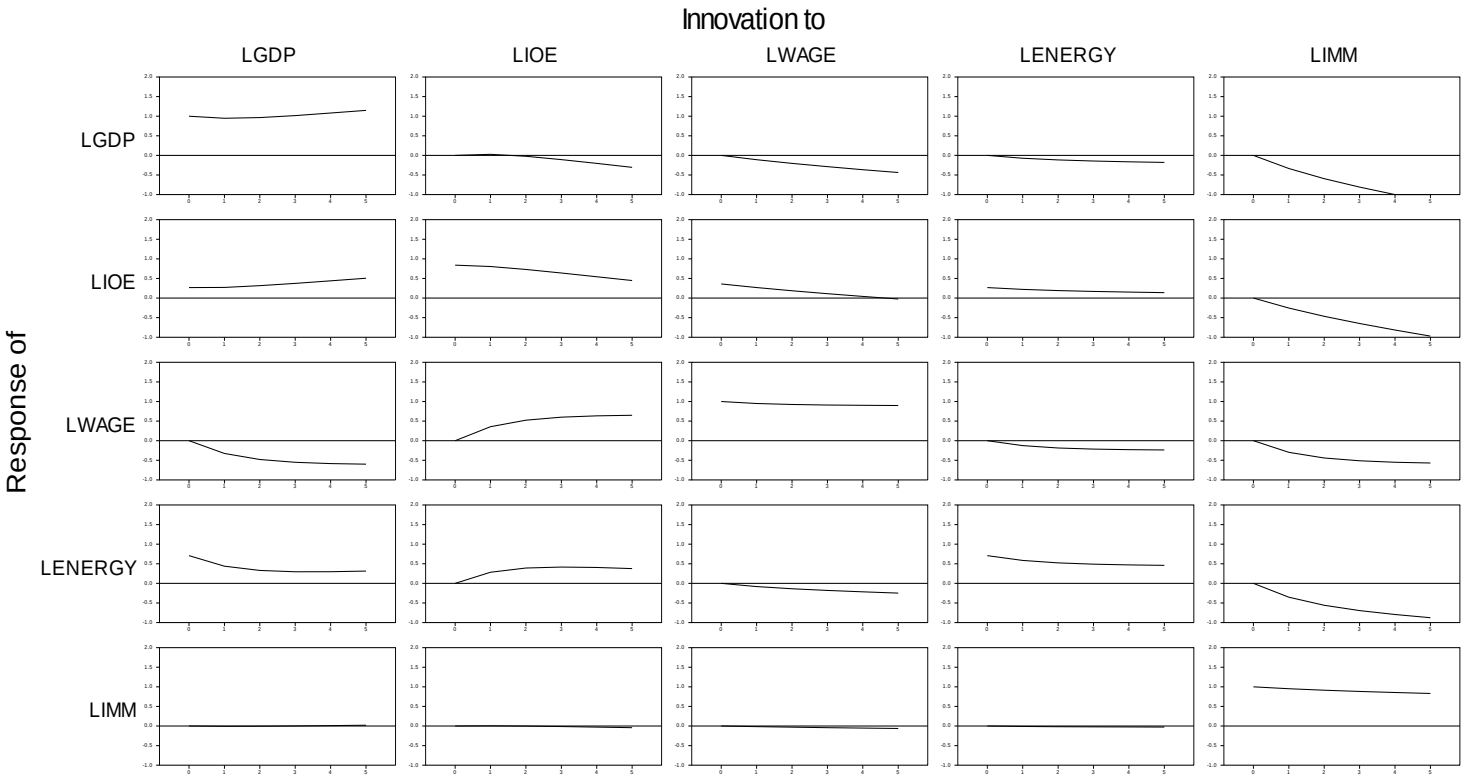

Figure A.4. Impulse response functions innovation is applied to the column heading variables and responses are shown by the row heading variables for a VECM model with lag one and rank two