Three Essays on CGE Modeling, Education Economics and Energy Economics

by

Lei Zhang

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Approved by

Henry Kinnucan, Chair, Professor of Agricultural Economics and Rural Sociology
Henry Thompson, Professor of Economics
Paul Patterson, Professor of Agricultural Economics and Rural Sociology
Huajun Huang, Associate Professor of Mathematics

Abstract

This dissertation consists of three essays in economics on CGE modeling, education economics and energy economics.

The first essay focuses on quantifying the economic contribution of the automotive industry to Alabama's economy using a static computable general equilibrium (CGE) model. The findings indicate that the automotive industry's contribution to Alabama's economy has been overestimated. The findings also show that the impacts of the industry are almost evenly distributed across Alabama. A five percent hypothetical year-to-year increase in automotive demand raises the GSP, government revenues and household income by roughly 0.05 percent, 0.01 percent, and less than 0.2 percent respectively, which reveals that Alabama is far from being over-dependent on the automotive industry and highlights the diversification of the Alabama economy.

In chapter 2 the propensity score matching methods was used to evaluate the causal association between early teen drinking onset and high school dropout status by region and by gender. Based on the National Longitudinal Surveys of Youth 1997 (NLSY97) data set, the results demonstrate that this causal effect is strong for rural male adolescents. Early drinking onset significantly positively raises their dropout rate by 5 percent. However, the causal effect among other groups is insignificant. Sensitivity analysis shows that the findings are not robust to the unobserved factors.

Chapter 3 explores the causal relationships between CO_2 emissions, electricity consumption, and economic growth for a group of 15 Sub-Sahara African (SSA) countries from 1980 to 2007 using panel cointegration and panel vector error correction modeling methods. The findings demonstrate that in the long run electricity consumption has a statistically significant and positive impact on CO_2 emissions. However, the inverted U-shape Environmental Kuznets Curve (EKC) hypothesis does not hold in the SSA countries' case. The panel causality tests indicate that there is short-run uni-directional causality, which runs from CO_2 emissions to

economic growth and runs from economic growth to electricity consumption. At the same time, there are bidirectional causality between electricity consumption and CO_2 emissions and uni-directional causalities running from economic growth to electricity consumption and CO_2 emissions respectively in the long run.

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Table of Contents

List of Tables

List of Figures

Chapter 1 Is Alabama over-dependent on its Automotive Industry? Evidence from a Computable General Equilibrium Analysis

1.1 Introduction

The automotive industry in Alabama has undergone substantial changes over the past two decades. Prior to 1997, Alabama had not produced a single car. Since 1997, when Mercedes-Benz rolled off its first automotive production line, the total vehicle production in Alabama increased steadily from roughly 68,000 in 1998 to 711,000 in 2010 (EDPA2011), with a peak of approximately 730,000 in 2007 (EDPA, 2009). Besides providing job opportunities and increasing workers' incomes, it has also stimulated the economic activities in other sectors. The automotive industry and its ancillary industries accounted for over 16 percent of the state's employment, which included 48,457 direct jobs and 85,769 indirect jobs in 2007 with an annual payroll of about $5.2 billion (Ahn 2005; AAMA, 2008). The automotive industry in Alabama has also excelled in international trade, although these foreign auto manufacturers' targets are the U.S. domestic market. Motor vehicles have been ranked Alabama's top export[1] since 2004. Finished automotives topped the list with about $5 billion, accounting for more than 31 percent of Alabama's total exports in 2008 (Export Alabama Initiative).

The statistics above suggested the growing importance of Alabama's automotive industry. Like Michigan, whose recent economic decline is ascribed to its traditional heavy reliance on its automotive industry, the Alabama economy was also challenged by the automotive industry's downturn in the economic recession beginning in late 2008. Concerns whether or not Alabama's

[1] "Exports" is referred to the commodities transported abroad.

increasing dependence on its automotive industry will cause it to suffer the same fate as Michigan gradually arise, especially after the recent economic downturn. Generally speaking, heavy reliance on a specific industry can be detrimental to the economy under the current uncertain economic environment. Take Michigan whose past prosperity is mainly due to its powerful automotive industry as an example, with the decline of its automotive industry, especially after the bankruptcies of GM and Chrysler, the less diversified Michigan economy has impeded its progress to future prosperity. The case of Michigan reveals the significance of economy diversification. In order to weather future economic uncertainty, putting too many of economic eggs into one basket is risky.

The primary purpose of this paper is to investigate whether or not Alabama is over-dependent on its automotive industry by quantifying the effects of auto export expansion across Alabama's economy. A secondary goal is to determine which counties in Alabama are most reliant on the automotive industry. The motivation for this research results from the increasing importance of the Alabama automotive industry under the economic uncertainty context. Given its growing importance to the Alabama economy, an improved understanding of the nature and extent of the economic contribution of the automotive industry to the Alabamian economy is necessary. A static regional CGE model is applied in the context of the Alabama economy in this paper, with special focus on its effects on macroeconomic indexes, employment, labor income, and household welfare. To my knowledge, this study is the first effort to rigorously quantify the contribution of the Alabama automotive industry. The results show that the automotive industry has a much less strong performance than expected, which, to some extent, implies that Alabama is sufficiently diversified to deal with future economic uncertainty. The findings also demonstrate that the impacts of the automotive industry are almost evenly distributed across

Alabama regardless of the length of run, despite the fact that the automotive industry has a relatively larger impact in a longer span of time. In other words, urban counties where auto plants located are as vulnerable as the other counties.

Although the automotive industry is important to the overall U.S., especially to states like Alabama and Michigan, little literature has addressed its contribution to the economy. To my best knowledge, only two peer-reviewed studies investigating automotive industry's impact in CGE models have been published. Haddad and Hewings (1999) constructed an interregional CGE model for Brazil to evaluate the short-run impact of the new private investment and technology enhancement in the automobile industry on Brazil's three regions. The findings show that investment and technology enhancement contribute to the employment of the country as a whole, as well as its differential impacts on those regions. Mitkova (2009) divided the Slavic economy into the automotive sector and the rest of sectors using 2004 data. Shocking the CGE model shows that the automotive industry contributes to the economic development of Slovakia in terms of household welfares and GDP. The findings argue that urban households are likely to be better off than rural households in terms of equivalent variations and incomes in the short run.

This study filled this gap by quantifying the contribution of the automotive industry to the Alabama economy. The present study departs from the two above-mentioned studies in several aspects. To begin with, both studies focus on short-run analyses, while the present study uses both short and intermediate run analyses. This can relatively comprehensively reflects the impact of the automotive industry, considering Keynesian specification practically reflects the auto boom's impact on the relatively high unemployment rate across Alabama. In addition, the impact on the economy is not quickly observable and needs some time to show up, thus avoiding the biased conclusion. Also, the CGE models in those two studies are built on national levels.

However, the economic effects of the automotive industries on the Brazilian economy and Slavic economy likely differ from those on the Alabamian economy, suggesting an Alabama-based regional CGE methodology. Moreover, a better understanding of the welfare changes of different households in distinguished regions is especially important in policy-making processes. Hence, those separate welfare change estimates are presented to investigate the differential welfare benefits among different categories of households.

The rest of the paper is organized as follows. The next section provides an overview of Alabama's automotive industry. The third section provides a description of the methodology and data sources. Results of the simulation analyses are described and discussed in the fourth section. Section five presents the sensitivity analysis and the final section summarizes and concludes the paper.

1.2 Overview Alabama's Automotive Industry

The automotive industry is considered the pillar industry of the Alabama economy due to a number of automotives plants in the state. Since Mercedes-Benz set up its plant in 1993, a number of foreign automakers have set up plants in Alabama. From the Mercedes-Benz plant in Vance in 1993, to the Honda plant in Lincoln in 1999, to the Hyundai plant in Montgomery in 2002, Alabama is currently home to three major auto assembly plants (EDPA, 2009). Further, Navistar and Toyota also chose Alabama to manufacture their engines in Huntsville in 2001(EDPA, 2009). Moreover, other automakers also have future plans to build plants in Alabama. For example, Isuzu, another potential major automaker, will build a plant and operate business in Alabama in a location where there had been few automotive presences before 1997.

Auto production has increased steadily, and the production capacity, which increased significantly from 80,000 in 1997 to 760,000 in 2007(EDPA, 2009), was ranked the third largest in the South and the fifth largest in U.S. in 2005(EDPA, 2009). In addition, besides providing a substantial number of jobs that offset losses in mining, agriculture, and textiles, the automotive industry also generated a relatively higher wage rate and billions of dollars in annual sales and GSP. In 2009, the average weekly wage for auto workers in the state was $1,325, which was higher in comparison to $872 for all manufacturing industries and $745 for all industries (EDPA, 2009). The automotive industry's direct contribution to the GSP was $1,103 million or 1.1 percent in 1997 and $3,219 million or 2.0 percent in 2007 (AAMA, 2008).

The situation worsened Alabama's industries in late 2008 owning to the national economic recession. The influence of the housing bubble and the collapse of the financial sector led to scarce availability of credit and lower consumer confidence. Alabama was not immune from the recession, and its automotive industry was adversely affected by the sluggish economy. Auto production dropped about 40 percent, roughly from 670,000 in 2008 to 480,000 in 2009. The amount of exported vehicles fell from $5 billion in 2008 to $3.4 billion in 2009 (EDPA, 2009). With the economy recovery, the auto production has begun to rebound. Auto production in 2010 is about 711,000 units, a 52 percent increase from 2009 auto production. Considering future uncertainty, it is timely and necessary to examine whether cyclical fluctuation of the automotive production will has an influential effect on the Alabama economy or not.

1.3 The Modeling Framework and Data

The Alabama economy is not internally homogeneous, with great variations across counties. As such, a state-level assessment is not enough to get a deep understanding of the contribution of the automotive industry on the regional economy. The economic effects of the automotive sector are usually strongest in the urban counties where all three automotive assembly plants are located. However, the non-urban counties may have also felt the benefits of the auto boom since increased auto demand directly or indirectly support business operated in both urban and rural counties. To analyze the impact of the expanding auto demand on Alabama's regional economy, specifically, its influence on the "persistently poor" Black Belt[2], Alabama is broken down into three regions for the purpose of analysis: the Black Belt, the urban counties [3]and the rest of Alabama (See Figure 1 for more detailed information).

Two approaches, partial equilibrium models and computable general equilibrium models, are often used in regional economic analyses. To represent complicated economic relationships, partial equilibrium analyses, which often focus on specific sectors and ignore the rest of an economy, are insufficient. Therefore, it is necessary to build up a CGE model that handles an economy as a whole.

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[2] The twelve counties identified as "distressed" Black Belt counties are Bullock, Choctaw, Dallas Greene, Hale, Lowndes, Macon, Marengo, Perry, Pickens, Sumter, and Wilcox, according to the Black Belt Action Committee (http://blackbeltaction.alabama.gov/).

[3] There is no universally accepted definition of "urban counties". In this paper, the determination of urban counties is based on the ARHA's (Alabama Rural Health Association) Method (www.arhaonline.org). However, Talladega, which is not defined as urban by the ARHA, is considered as an urban county in the present study.

Recently, the CGE approach has been widely used in regional policy analyses (Partridge and Rickman, 2007). This approach is generally based on comparative static analysis where the base equilibrium is compared with the new equilibrium after the exogenous shocks have taken place. Unlike partial equilibrium models, CGE models take into account the inter-industry linkages and intend to model all linkages in an economy. The CGE approach is deemed a more proper framework for implementing economic impact analyses, therefore it is adopted to investigate the automotive sector's impact on the Alabama economy.

A CGE model is based on a Social Accounting Matrix (SAM) which provides data used to calibrate and solve the CGE model[4]. In this study, three separate SAMs for each region are constructed using 2007 IMPLAN (Impact Analysis for PLANning) data and software. IMPLAN divides the Alabama economy into 440 sectors which are aggregated into 12 sectors according to the aggregation scheme listed in Table 1 in this study.

The CGE model[5] in this study is modified and based closely on the CGE model constructed by Holland, Stodick and Devadoss (2004) and Lofgren (2000). The model, which was originally used in tax analysis in Washington, can also be extended to do the likely economic analyses. Hence, it is adapted to the Alabama context here. The PATH solver of GAMS software is applied to generate and solve simultaneous non-linear equations in the CGE model. Five blocks, consisting of households, firms, government, trade, and macro closures, are presented in the following subsections.

1.3.1 Households

[4] However, calibration is acknowledged as a weakness of this method (Shoven and Whalley,1984)

[5] The model equations are available upon request from the author.

IMPLAN provides data for nine distinct households. Following the conventional approach, nine households are aggregated into three representative rational households .This study considers a household whose income is over $75 thousand as a high income household, $25 thousand to $75 thousand as a middle income household and under $25 thousand as a low income household. A representative household in each category is assumed to maximize the Stone-Geary utility function by choosing its optional consumption bundle. This study also assumes that the household budget consists of income and consumption expenditure and the endowment of household includes capital and labor. Moreover, the sources of household income revenues are returns on primary factors, transfers from the governments, other households, the rest of U.S., and the rest of the world. Each household also allocates its consumption expenditure to private consumptions, taxes and savings.

1.3.2 Firms

In this study each sector is aggregated by many firms, but each sector is regarded as a single representative firm assumed to produce a homogeneous product according to a nested production function. The representative firm's problem is to maximize its profits subject to its budget constraint.

Two levels are formulated in the production process[6]: the production of composite goods and the production of gross output. At the first level two primary factors, labor and capital, are employed in the CES production process to produce the composite goods. At the second level, the firms use the intermediate inputs with the composite goods to produce the final goods under Leontief technology.

[6] The figure of the structure of production process is available upon request.

The elasticity of substitution between labor and capital for each industry is borrowed from de Melo and Tarr (1992). Given the fact that there is little guidance about the determination of the supply elasticities of labor and capital, following Holland et al.(2006), I assume that the supply elasticity of labor is set to two and the supply elasticity of capital is set to one in the medium run for all regions. While in the short run, both supply elasticities of labor and capital are set to 0.5.

1.3.3 Government

As specified in IMPLAN, the government in this model has two levels: the federal government and a combination of state and local government. This paper has attempted to do the same by dividing the government into two levels. Governments are assumed to balance their budgets and they affect the economy mainly through two ways: taxation and government spending. Taxation includes income taxes on households, investment, and indirect taxes which are levied from production activities and tariffs. Government spending consists of government consumption, government savings, transfers to household and payments to foreign nations. Like households and firms, governments can lend or borrow as well.

1.3.4 Trade

In order to analyze a regional economy within a country, taking into consideration its connection to the rest of the country and the world is necessary. As a result, both domestic trade and international trade are implicitly included in this model. In other words, a representative firm sells its products outside of the region within the U.S., and some of the products are also sold outside of U.S. Armington assumption was used to differentiate domestic and imported goods which are imperfect substitute to each other. Given the two kinds of trade, a two-level Armington function was used. In the first level, regionally produced goods were distinguished from domestically imported goods which are imperfect substitutes for each other; in the second level, substitution between domestic imports and foreign imports is allowed.

The CET function is used to decide the production possibility of the choice between domestic goods and export goods. Like the CES function, the CET function also has a two-level structure: it not only differentiates exported goods and domestically consumed goods but also distinguishes exports to the rest of U.S. and to the rest of the world. Contrary to the routine adopted by most regional CGE modelers, the salient feature of this study is to use disparate elasticities on different levels, which overcomes the weakness as pointed out by Partridge and Rickman (2007). Since the regional economy is more open than national economy and the wide range for elasticities are specified in different sources, the elasticities in regional analyses usually have higher values. In contrast, the elasticities of substitution for regional analyses are smaller than those on national levels in analyses (Holland, 2010).The values of the CES and CET elasticities used in this paper are based on estimates as specified in de Melo and Tarr (1992).

1.3.5 Macro Closures

Two popular closures[7], Neoclassical and Keynesian are applied to the model. Neoclassical closure is often used in short-run analyses (one to two years), while Keynesian closure is applied to medium run analyses (three to five years).

Neoclassical closure assumes that the labor supply and capital supply are fixed so only the wage rate and the capital rent rate can be adjusted to clear the factor markets. Although Keynesian closure specifies the same capital supply, it assumes that the labor supply is perfectly

[7] It is still controversial which macro closure better fits the regional economic analyses. Rickman (1992) argues that the results from the neoclassical specification seem better. In contrast, Kraybill (1993) contends Keynesian closure is more practical for regional economy analysis.

elastic and the wage rate is fixed. In the neoclassical closure, investment is endogenous so that it is determined by various kinds of savings. In contrast, under the Keynesian closure, saving is endogenous so the Keynesian model is considered the investment driven model.

Under either specification, a set of prices will clear both factor markets and commodity markets. The factor market equilibrium requires that the employed factors in each sector equal their endowment. The commodity market equilibrium requires that the supply of each commodity equals to the demand of each commodity. In addition, the CPI is treated as the numeraire in this paper.

1.4 Empirical Result and Analysis

The aim of this section is to identify the impact of the auto export demand expansion on economic growth and explore whether Alabama has a diversified economy. Suppose that Alabama exports all of its produced vehicles out of the state, regardless of other states in the U.S. or abroad. Given an already established industry, a hypothetical five percent year to year increase in auto export demand is assumed to investigate its potential impact. It is reasonable, as it reflect the magnitude of the auto production growth in Alabama. To further simplify the analysis, this study further assumes that the auto export demand increase five percent for both domestic and international trade. Therefore, we have two simulation scenarios: one is shocking the model by increasing the auto export demand by five percent in the short run; the other is five percent increase in auto export demand in the medium run. Table 2 through 6 present the simulation results which are in the percentage terms with the exception of those in the lower panel of Table 5 which are in the quantity changes.

1.4.1 Macroeconomic effects

Table 2 presents the percentage changes in selected macroeconomic variables of the five percent hypothetical increase in the auto demand under different model specifications with varying assumptions about the labor market adjustment and capital mobility. An overview of the results demonstrates that the demand shocks have different but unanimously smaller impact across Alabama.

Under neoclassical closure, total labor supply is fixed in each specific region. Hence, firms can only adjust the wage rates in response to the expanding auto demand so the percentage change of labor supply is zero. Surprisingly, three regions benefit almost equally from the auto boom in terms of percentage changes in GSP, average wage rate, labor supply, and government revenues. The expanding demand for automobiles lifted the GSP very slightly only by 0.05%, 0.04% and 0.06% respectively for those three regions as shown in Table 2. The tiny effect of increased auto demands on GSP is unsurprising, considering the fact that the automotive industry only accounted for two percent of GSP in Alabama. The automotive industry caused little growth in terms of GSP which reflects the diversification of the Alabama economy. Also, the fact that the government revenue increased only one percent and average wage rate raised only by 0.05% in all three regions due to auto export expansion corroborate its tiny effects again. Due to regional spillover effects, the Black Belt also benefits as well from the increased auto demand in terms of GSP, the wage rate and the government revenue which rose by 0.04%, 0.05% and 0.01% respectively.

Under the Keynesian specification, where firms adjust their employment in response to the increased auto demand, the picture changes. The economy adjusts the number of workers instead of the wage rate which is fixed to reflect the wage rigidity. As a result, if auto labor demand rises, workers from other regions will migrate into the region. Otherwise, labor forces will migrate out of the region. Compared with the short run neoclassical CGE, the increased auto demand has a greater impact on each of the macroeconomic variables. For example, GSP and the government revenue rise by 0.09% and 0.04% respectively for Alabama, as opposed to 0.06% and 0.01% under the neoclassical specification. All three regions are better off in the Keynesian closure than in the neoclassical closure, but the impact is still small in the medium run. In sum, the overall impact of auto expansion is definitely positive but small from a macroeconomic perspective. The unexpected small contribution of the automotive industry implies that Alabama is not over-dependent on its automotive industry and implicitly suggests the fact that Alabama's economy is sufficiently diversified.

1.4.2 Impact on Employment

Table 3 indicates a mixed picture of the employment effects resulting from the auto demand expansion.

In the short run, the labor force is fixed in respective regions, so the increased auto demand can only draw labor from other industries in the same region. Higher wages in the automotive industry can easily drive workers from the automobile horizontal industry to the automotive industry due to the similar skills and backgrounds required by these sectors. Under the neoclassical closure, although the automotive industry experiences a moderate increase (around four percent) in employment, most industries experience in job losses in all three regions. Specifically, the automobile horizontal industry is most negatively affected by the increased automobile demand which drive workers with similar skills from other industries to the automotive sector. Employment in the automotive horizontal industry has declined by 0.24% in the urban counties and 0.37% in the entire state of Alabama.

In the medium run, the labor force is interregionally mobile and wage rates are fixed. Under these assumptions, the increased auto demand not only brings about employment in the auto industry but also gain jobs in the other industries. However, its impact on employment in non-automotive industry is tiny. As shown in Table 3, it is evident that most industries have experienced job increases. Besides benefiting the workers in the automotive industry, the employment effects of the automotive sector also extend to workers who are not directly participating in any auto-making activities, which highlight the sectoral spillover effects. For example, the trade, service and transportation industries increase slightly by 0.20%, 0.05% and 0.05% respectively in employment in Alabama.

1.4.3 Labor Income Effects

Table 4 indicates the labor income effects caused by the increased auto demand. As expected, for the most industries, the medium run effects are more likely to be positive and larger than the short run effects. Again, the reason is that labor supply is fixed in the short run, while in the medium run, labor forces are mobile across regions and unemployment exists. Increased auto demand not only attracted workers from other industries, for example, horizontal industries, but also attracted the unemployed.

Apparently, as shown in Table 4, the labor income of the auto industry increases more rapidly than in other sectors, while the auto horizontal industry undergoes losses in those regions. Further, some industries which are adversely affected under the neoclassical closure are positively influenced under the Keynesian specification, such as, the utility industry, but not vice versa. It is of interest to notice that the negative effects to most industries under the neoclassical specification are mitigated when they are examined under the Keynesian closure excluding the auto horizontal industry. Take the labor incomes in the agricultural industry as an example, the labor incomes changed from -0.12 percent,-0.03 percent and -0.11 percent to -0.11 percent,-0.03 percent and -0.09 percent respectively for the three regions.

Overall, the figures in Table 4 imply that the auto expansion's effect on labor income is small, especially to workers from the non-auto industries. From a policy point of view, as a newly established industry, its impact to the economy is still limited. Alabama is still far from being over-dependent on the automotive industry which highlights the diversification of the Alabama economy.

Another important fact is that the percentage changes of labor incomes in Table 3 are the same as the percentage changes of employment in Table 4 under the Keynesian closure. Given that the wage rates are fixed in the medium run, the firms adjust the employment in response to the auto demand which results in the same changes in employment and labor incomes.

1.4.4 Income and Welfare effects

Table 5 demonstrates the income effects and the welfare changes which are measured by equivalent variation (EV hereafter) accounting for changed price effects for each household category in all regions. The welfare changes reflect how much better off the households would be from the rise in auto export demand. Unlike the income measure, it takes the changes both in price and income into account. Obviously, the income and welfare gains are not distributed evenly across regions and households. The impact on both income and welfare to the households in all regions under both closures is positive. The medium run effect is larger than the short run effect. Under both specifications, the percentage increase in income and the increase in EV are larger for middle income household than for the other two types of household. However the average EV, which is obtained by dividing the total EV by number of household, shows that high income households gain most in the short run with EV per household ranging from $ 32.00 to

$ 55.34 while middle income households benefit most in terms of EV in the range from $ 54.23 to $ 128.67.

The households in the Black Belt counties, under the neoclassical closure, middle income households benefit more than low and high income households in terms of income changes and total EV. The average EV of high income households is 32 which is the largest. The wealth gap in the Black Belt region became wider after the shocks. But under the Keynesian closure, with more people joining in the labor force, the income change of low income households is increased to 0.05 percent and its total equivalent variation is $ 0.17 million. These results imply that the auto boom has only relieved the poverty in the Black Belt region to a very limited extent.

1.5 Sensitivity Analysis

From a policy analysis standpoint, one of the major problems of CGE modeling approach is the reliability of the model. Due to the heavy dependence on the elasticities from the literature, therefore, sensitivity analyses should be undertaken on certain parameters to assess the robustness of the model. In particular, two sensitivity experiments were done. First, the sensitivity to a changed elasticity of factor substitution ρ between labor and capital in the automotive industry was examined. Secondly, the model's sensitivity to the changed export demand elasticity α was also explored.

The factor substitution elasticity between labor and capital for the automotive industry used in simulation is from de Melo and Tarr (1992). The value of 0.81 is referred to as the "central" value. Given that the value is not estimated particularly for the Alabama automotive industry and Alabama's ample quality labor forces, the low estimate value of 0.50 from de Melo and Tarr (1992) was used as an alternative to test the robustness of the model. The original export demand elasticity is assumed at -5. By changing its value to -2 for the purpose of comparison, the model's sensitivity to the export demand elasticity could be examined. Parts of the results[8] are summarized in Table 6.

Based on the results presented in Table 6, the findings demonstrate that two different factor substitution elasticities between labor and capital of the automotive sector generate almost entirely same results. This implies and highlights the model's strong robustness to the choice of factor substitution elasticities. The results from the lower panel also indicate that the simulation results are insensitive to the changes of the value of export demand elasticity.

1.6 Conclusion

The undertaken study is in an attempt to measure the contribution of the automotive industry to the Alabama economy. Impact of auto demand shocks was examined under two model specifications. A general equilibrium analysis on the auto industry generated a number of important conclusions.

First, the most important finding shows that the automotive industry's impact on the Alabama economy is too small to have much effect on Alabama's economy, which highlights the fact that the Alabama economy is sufficiently diversified. Secondly, the impact of the auto sector extends well beyond the urban counties, and the effects are almost evenly distributed across Alabama. Third, the Keynesian closure produced larger impact than the neoclassical closure. Finally, sensitivity analyses indicated that the model is more robust to the substitution elasticity but less robust to the export demand elasticity.

[8] The full result is available upon request.

This study fills the gaps in the literature since it is the first study which empirically investigates the contribution of automotive industry to Alabama's economy. The results suggest that the diversification of Alabama economy will prohibit it suffering the same fate as Michigan. Given that the automotive industry accounts for 2 percent of GSP, it plays a less important role in the Alabama economy than expected. In light of this, in order to further develop the Alabama economy, especially the Black Belt economy, relying on the automotive industry is not enough. Further development of other industries such as the agriculture industry or service industry might be more effective to help Alabama relieve the persistent poverty. Moreover, this study also presents some valuable conclusions to aid policy makers to identify not only the affected stakeholders of the auto demand expansion, but also the direction and magnitude resulting from the auto demand shocks. Given that the impacts of automotive industry are almost evenly distributed across Alabama, cyclical downswing in auto sales will not only hurt the urban counties but also the entire state of Alabama. However, these effects are small overall. Finally, the empirical findings here also have implications for other states, such as South Carolina and Ohio, where the automotive industries play important roles.

Table 1. The Aggregation Scheme for the Alabama Regional Economy

Sectors	Aggregated Individual IMPLAN Sector Codes
Agriculture	1-19
Auto	276-277,279,283
Auto parts	320,362,414-415
Auto horizontal	278,280-282,292-294
Construction	34-40
Manufacturing	41-291,295-318
Mining	20-30
Trade	319
Service	321-331,336-361, 363-427
Transportation	332-335
Utility	31-33
Miscellaneous	428-440

Table 2. Macroeconomics Effects of a 5% Increase in Demand for Alabama-Produced Automobiles (percent change from benchmark)

Variable	Urban Impact		Black Belt Impact		State Impact	
	Neoclassical Closure	Keynesian Closure	Neoclassical Closure	Keynesian Closure	Neoclassical Closure	Keynesian Closure
GSP	0.05	0.08	0.04	0.07	0.06	0.09
Average Wage Rate	0.03	0.00	0.05	0.00	0.05	0.00
Labor Supply	0.00	0.06	0.00	0.07	0.00	0.07
Gov Revenue	0.01	0.02	0.01	0.01	0.01	0.04

Source: Author's Calculation.

Table 3. Employment Effects of a 5% Increase in Demand for Alabama-Produced Automobiles (percent change from benchmark)

Variable	Urban Impact		Black Belt Impact		State Impact	
	Neoclassical Closure	Keynesian Closure	Neoclassical Closure	Keynesian Closure	Neoclassical Closure	Keynesian Closure
Agriculture	-0.15	-0.11	-0.08	-0.03	-0.15	-0.09
Auto	3.19	3.21	4.16	4.22	3.58	3.62
Auto parts	0.02	0.10	0.02	0.08	0.02	0.10
Auto Horizontal	-0.24	-0.24	NA*	NA*	-0.37	-0.35
Construction	0.05	0.02	0.01	0.02	0.04	0.02
Manufacturing	-0.12	-0.08	-0.06	-0.01	-0.13	-0.07
Mining	-0.17	-0.14	-0.07	-0.01	-0.17	-0.12
Trade	0.13	0.19	0.02	0.10	0.12	0.20
Service	-0.04	0.03	-0.03	0.05	-0.04	0.05
Transportation	0.00	0.06	-0.01	0.06	-0.01	0.05
Utility	-0.05	0.01	-0.03	0.04	-0.05	0.02
Miscellaneous	-0.04	0.01	-0.06	0.02	-0.05	0.02

Source: Author's Calculation.

*Almost no these products are produced in the Black Belt counties. So the number here is meaningless.

Table 4. Labor Income Effects of a 5% Increase in Demand for Alabama-Produced Automobiles (percent change from benchmark)

Variable	Urban Impact		Black Belt Impact		State Impact	
	Neoclassical Closure	Keynesian Closure	Neoclassical Closure	Keynesian Closure	Neoclassical Closure	Keynesian Closure
Agriculture	-0.12	-0.11	-0.03	-0.03	-0.11	-0.09
Auto	3.23	3.21	4.21	4.22	3.63	3.62
Auto parts	0.06	0.10	0.06	0.08	0.06	0.10
Auto Horizontal	-0.21	-0.24	NA*	NA*	-0.32	-0.35
Construction	0.09	0.02	0.05	0.02	0.09	0.02
Manufacturing	-0.09	-0.08	-0.01	-0.01	-0.09	-0.07
Mining	-0.14	-0.14	-0.02	-0.01	-0.12	-0.12
Trade	0.17	0.19	0.07	0.10	0.17	0.20
Service	-0.01	0.03	0.02	0.05	0.01	0.05
Transportation	0.04	0.06	0.04	0.06	0.03	0.05
Utility	-0.02	0.01	0.02	0.04	-0.01	0.02
Miscellaneous	-0.01	0.01	-0.01	0.02	-0.01	0.02

Source: Author's Calculation.

*Almost no these products are produced in the Black Belt counties. So the number here is meaningless.

Table 5. Income and welfare Effects of a 5% Increase in Demand for Alabama-Produced Automobiles

Income Effect						
	Urban Impact		Black Belt Impact		State Impact	
Variable	Neoclassical Closure	Keynesian Closure	Neoclassical Closure	Keynesian Closure	Neoclassical Closure	Keynesian Closure
Low Income HH	0.03	0.09	0.01	0.05	0.03	0.09
Middle Income HH	0.05	0.17	0.03	0.08	0.05	0.16
High Income HH	0.03	0.05	0.02	0.03	0.03	0.05

Welfare Effect												
	Urban Impact				Black Belt Impact				State Impact			
Variable	Neoclassical Closure		Keynesian Closure		Neoclassical Closure		Keynesian Closure		Neoclassical Closure		Keynesian Closure	
	Total	Ave.	Total	Ave.	Total	Ave.	Total	Ave.	Total	Ave.	Total	Ave.
Low Income HH	3.00	7.94	10.37	27.45	0.17	3.72	0.58	12.70	5.34	7.61	17.86	25.46
Middle Income HH	20.28	39.11	66.71	128.67	0.81	24.40	1.80	54.23	35.12	39.60	101.73	114.69
High Income HH	10.92	54.72	15.24	76.37	0.24	32.00	0.32	42.67	16.00	55.34	22.51	77.86

Note: The numbers in the upper panel are in the percentage changes and the numbers in the lower panel are in the quantity changes. The units of total EV and average EV are $US million and $US respectively.

Table 6. Sensitivity analysis of changes in the factor substitution elasticity and the export demand elasticity

Variable	Urban Impact				Black Belt Impact				State Impact			
	Neoclassical Closure		Keynesian Closure		Neoclassical Closure		Keynesian Closure		Neoclassical Closure		Keynesian Closure	
	α= -2	α= -5	α= -2	α= -5	α= -2	α= -5	α= -2	α= -5	α= -2	α= -5	α= -2	α= -5
GSP	0.08	0.05	0.11	0.08	0.06	0.04	0.08	0.07	0.09	0.06	0.12	0.09
Average Wage Rate	0.06	0.03	0.00	0.00	0.07	0.05	0.00	0.00	0.07	0.05	0.00	0.00
Labor Supply	0.00	0.00	0.08	0.06	0.00	0.00	0.08	0.07	0.00	0.00	0.10	0.07
Gov Revenue	0.02	0.01	0.03	0.02	0.01	0.01	0.01	0.01	0.02	0.01	0.03	0.04
Low Income HH EV	4.52	3.00	14.24	10.37	0.25	0.17	0.69	0.58	7.74	5.34	23.86	17.86
Middle Income HH EV	30.15	20.28	91.16	66.71	1.12	0.81	2.12	1.80	50.21	35.12	133.07	101.73
High Income HH EV	16.17	10.92	20.44	15.24	0.33	0.24	0.37	0.32	22.77	16.00	28.77	22.51
	ρ =0.5	ρ=0.81	ρ=0.5	ρ=0.81	ρ=0.5	ρ=0.81	ρ=0.5	ρ=0.81	ρ=0.5	ρ=0.81	ρ=0.5	ρ=0.81
GSP	0.05	0.05	0.08	0.08	0.04	0.04	0.07	0.07	0.06	0.06	0.09	0.09
Average Wage Rate	0.03	0.03	0.00	0.00	0.05	0.05	0.00	0.00	0.05	0.05	0.00	0.00
Labor Supply	0.00	0.00	0.06	0.06	0.00	0.00	0.07	0.07	0.00	0.00	0.07	0.07
Gov Revenue	0.01	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.04
Low Income HH EV	3.00	3.00	10.36	10.37	0.18	0.17	0.58	0.58	5.34	5.34	17.85	17.86
Middle Income HH EV	20.29	20.28	66.64	66.71	0.81	0.81	1.80	1.80	35.13	35.12	101.65	101.73

High Income HH EV	16.17	16.17	15.22	15.24	0.24	0.24	0.32	0.32	16.00	16.00	22.48	22.51

Note: All variable are present in percentage changes except the three total equivalent variations (EV).

Figure 1. Division Map of Alabama

Note: The black regions are Black Belt and the gray counties are urban counties. Three auto assembly plants are located in Montgomery, Talladega, and Tuscaloosa respectively.

Chapter 2 Does Early Teen Drinking Onset Affect High School Dropout Rate? Evidence from NLSY97

2.1 Introduction

The high school dropout "crisis" has raised wide concern in recent years. Although much attention has been paid to the high school dropout rates since the passage of the No Child Left Behind (NCLB) Act in 2002, there are still about 7,000 students who drop out each school day and around 1.3 million students fail to graduate each year (AEE, 2009). Successful completion of high school education is important to both the youngsters and the nation. At the individual level, teenagers who drop out of school are at high risk for juvenile delinquency, losses in wages and ending up with prison lives. For example, a student who fails to graduate from high school will earn roughly $9634 less than a high school graduate student each year (U.S. Bureau of the Census, 2006).At the national level, Richmond (2009) argues that the nation could save approximately $319 billion in lost wages during the lifetimes of the dropouts from the 2008 graduating class. Cochen (1998) also pointed out the external cost (about $300,000 per dropout) to the nation imposed by the dropouts.

However, the high school dropout crisis is a complex phenomenon and no single factor alone accounts for it. One of many potential risk factors that may sustain the rising high-school dropout rate is adolescent alcohol consumption. Despite public perception about the adverse effects of the alcohol use, the rising minimum legal drinking age (MLDA) to 21 in all states since 1988, a considerable number of high school students still consume alcohol and the alcohol use rate among high school students remains alarmingly high. Despite small declines, 41.2 percent of high school seniors reported the consumption of alcohol in the past 30 days. The prevalence of five or more drinks in a row within the past two weeks is 23.2 percent, according to the 2010 Monitoring the Future study.

There are three possible relationships between teen drinking and high school dropout rates. To begin with, one may expect a positive relationship between early drinking and high school dropout rates. Early literature has mainly identified two major mechanisms through which alcohol consumption affect schooling. On the one hand, drinking alcohol reduces the probability of graduation directly by impairing the adolescent's brain functioning and cognitive abilities (Nordby, 1999; Deas, 2000; Zeigler, 2005). On the other hand, schooling is indirectly negatively affected through pathways like reduced study time (Wolaver, 2002; Powell and Wechsler, 2003; Desimone, 2010), risky sex (Chesson et al. 2000) and teen pregnancy (Dee, 2001). However, early alcohol consumption can also be a consequence of dropping out. Lastly, it is also possible that those two are not directly linked, but correlated due to the existence of an unobserved factor.

The main purpose of this study is to explore whether or not there is a causal relationship between teen alcohol consumption and high school dropout status. A secondary goal of this paper is to investigate whether the effects of drinking on high school dropout rates differ with respect to region and gender. Understanding the link between drinking and dropping out contributes to enhancing the well being of the youngsters and reducing the occurrence of risky behaviors.

Compared with previous studies, this paper extends mainly in two directions. First of all, given the discrepancy of environment between urban and rural areas, adolescents living in urban regions are likely to face different social environments than their rural counterparts due to the disparity in socioeconomics characteristics. Moreover, the determinants of youth drinking may be different in both urban and rural adolescents, as suggested by Gfroerer et al. (2007). For these reasons, it is necessary to investigate this important causal effect under different settings. To my knowledge, few studies addressing this issue take regional differential into account, although the data in previous literature consisted of both urban and rural teenagers. This study takes this regional differential into account and separate regional causality analysis can provide important insights to policy makers and educators.

Female adolescents are more vulnerable to alcohol induced damage, such as brain damage (Hommer, 2003), cirrhosis (Loft, 1987) and nerve damage (Ammendola et al., 2000) than their male counterparts. Also, teen pregnancies resulting from abusive drinking behavior pose more threat to females than males with regard to schooling. Hence, gender differential is also taken into consideration.

This study is also unique in a number of important respects. The NLSY97 data employed in this study is more reliable than NLSY79 mainly due to the adoption of computer-assisted programs and is more nationally representative than regional survey data. Further, the novel propensity score matching (PSM) methods are used in this analysis. Several matching methods are used to investigate the nature of association between alcohol consumption and high school dropout rates. In addition, since the underlying assumption of these approaches is selection on observables, Rosenbaum bounds analysis is also used to perform analysis of the results' sensitivity to unobserved variables.

Controlling for a number of individual and family observables, the results show that there is a positive causal relationship between alcohol consumption and high school dropout rates. The findings also demonstrate that high school dropout rates in the urban regions are raised by roughly 1 percent for both genders due to alcohol consumption among adolescents. While this impact is more evident when it comes to the rural regions, alcohol consumption among teenagers leads to 5 percent increase in high school dropout rates for males and 1 percent for females in rural regions. However, Rosenbaum bounds analysis reveals that the effect of early teenage drinking is not robust to relatively little changes on the unobserved factors.

The rest of the paper is organized as follows. The next section provides an overview of relevant literature review. The third section provides a description of the propensity score matching methodology. Section four describes the data sources and variable definition. Thereafter, the results of the empirical analyses are described and discussed in the fifth section. The final section summarizes and concludes the paper.

2.2 Literature review

Most economic studies found that teen alcohol consumption has a negative impact on schooling. Early studies started by Benham and Benham (1982), who found that drinking alcohol can reduce schooling by approximately 1.5 years. Mullahy and Sindela(1989, 1994) use regression methods to explore the effects of early alcoholism on educational achievement using a sample of males aged 30 to 59 from the National Institute of Mental Health Survey Data. Their findings indicate that youth alcohol consumption reduces years of schooling. Yamada et al. (1996) found that a 10 percent rise in drinking raises the probability of dropping out by 6.5 percent for frequent drinkers and 2 percent for wine and liquor consumption, drawing on the NLSY79 data. Similarly, Register et al. (2001) found that everything else being equal, adolescent drug use is deemed responsible for one year's reduction of educational attainment. While carefully done, unfortunately, these studies fail to take endogeneity into consideration and thus devalue the reliability of their results. By contrast, Cook and Moore (1993), taking endogeneity into consideration, showed that alcohol consumption reduces schooling by 2.3 years.

More recently, some studies using the instrumental variable (IV) model arrived at similar conclusions. For example, Chatterji and Desimone(2005), drawing on the NLSY79 data, use drinking in the last month as an instrumental variable to estimate the effects of drinking on subsequent high school dropout rates. Their results indicate that drinking in the past month at age 15-16 lowers the possibility of graduating by at least 11 percent. Koch and McGeary (2005), also using NLSY79, found that early alcohol use leads to the reduction of the probability of graduating on time by 7-22 percent.

However, other economists have not found such a causal association between alcohol abuse among teenagers and schooling attainment. Koch and Ribar (2001) found that alcohol consumption's effect on schooling is likely to be small by constructing several estimators to examine data on same-sex sibling pairs from NLSY79. Dee and Evans (2003) call the results from Cook and Yamada's analysis into question given that statistical bias may be induced in those studies by the introduction of instrument variables. By contrast, the results from their studies show that the teen drinking's impact on educational attainment are small and statistically insignificant.

Relevant studies have also explored the effects of alcohol abuse on academic performance as well as schooling attainment. Wolaver (2002) found that binge drinking and intoxication lower grades directly by impairing cognitive skills and indirectly by reducing study hours. In contrast, William et al. (2003) found that drinking's positive direct impact on GPA is small and outweighed by the negative effects by reducing study times. In a more recent paper, Desimone

(2010) demonstrates the importance of omitted factors in deciding the association between drinking and GPA, and finds that drinking (except binge drinking) does not negatively affect GPA.

A growing body of literature has provided conflicting results regarding the association between alcohol use and schooling, owning to differences of the data sets employed and disparate measures of drinking and schooling. Divergent results from previous studies highlight the necessity to further investigate the teen alcohol consumption's effects on schooling.

Unlike previous studies, this study employs PSM instead of the linear regression and IV approaches which are widely used in previous studies. Traditional regression methods depend on a series of assumptions to provide the estimate of the treatment effect (Heckman, 1997). Although the IV approach can solve the endogeneity problem, often the appropriate instrumental variable is not available or the instrumental variable itself is a weak instrument which may lead to biased estimates (Bound, et al.1995). Given the limitations of both approaches, PSM has been proposed by Rubin and Rosenbaum in 1983 as an effective alternative and gradually gained popularity in economic literature for exploring the causal effects. PSM can produce good results, which are comparable to those from experimental data, if the quality of observational data is good (Rosenbaum and Rubin, 1983; Heckman et al., 1997; Smith and Todd, 2001).

2.3 Estimation Methodology

Ideally, the best method to detect the causal effects of teen drinking on high school dropout rates is through a randomized experiment where each teenager is randomly assigned into a treated group or an untreated group. In that case, taking the difference between mean outcomes of two groups can give us the direct effect of early alcohol drinking onset on schooling. However, these randomized experiments are usually infeasible due to various reasons, such as, associated cost or ethical considerations. In the absence of an experimental design, estimating the difference of the mean outcomes between treatment and comparison groups will lead to selection bias since possession of a specific preexisting characteristic may lead to a respondent to receive a treatment. In fact, in the real world, youths are not randomly assigned to alcohol consumption, which makes arriving at causal conclusions nearly impossible. PSM, in comparison to regression methods, can reduce the selection bias by comparing teens with similar characteristics when a random experiment is not feasible.

Formally, let Y_{i1} denote the potential outcome of respondent *i* who is treated and let Y_{i0} denote the potential outcome of an untreated respondent *i.* For each respondent *i*, only one potential outcome can be observed. Let D_i be an indicator variable: D_i =1 means respondent *i* fall into the treatment group, D_i =0 means respondent *i* falls into the control group. In this context, the respondents are divided into two groups: the treatment group (D_i =1) in which each respondent uses alcohol early and the control group (D_i =0) where the respondents do not consume alcohol. Then the observed outcomes and treatment effects for each respondent *i* are

$$Y_i=D_iY_{i1} + (1-D_i)Y_{i0} \quad (1)$$

$$\tau_i = Y_{i1}-Y_{i0} \quad (2)$$

where τ_i is the treatment effect for respondent *i*. The parameter of interest is the average treatment effect on the treated (ATT) given by:

$$ATT=E [Y_{i1}-Y_{i0} |D_i=1] =E [Y_{i1}|D_i=1] - E [Y_{i0}|D_i=1] \quad (3)$$

It can be calculated as the difference in dropout rates between the respondents in the drinking group and non-drinking group, conditional on the drinking condition. Since E [Y_{i0}| D_i=1] is unobservable, estimating ATT using E [Y_{i0}| D_i=0] rather than E [Y_{i0}| D_i=1] will result in selection bias.

Conditional independence assumption (CIA) and common support assumption, both of which were proposed by Rubin (1977, 1983), are used to overcome this difficulty. CIA states that after controlling for a set of covariates *X*, the outcome is independent of the treatment status conditional on those covariates, i.e. $Y_{i0}, Y_{i1} \perp D_i|X$, where ⊥denotes independence. The common support assumption is 0< prob(D_i=1|*X*) <1, where prob(D_i=1|*X*) denotes for the propensity score. Based on these two assumptions, the ATT can be rewritten as:

$$\text{ATT=E } [Y_{i1}\text{-}Y_{i0}\ |D_i\text{=1}] \text{ =E } [Y_{i1}|D_i\text{=1}] \text{ - E } [Y_{i0}|D_i\text{=0}] \qquad (4)$$

As we know, E [Y_{i0} |D_i=0] is equal to E [Y_{i0}|D_i=1] if CIA and common support condition hold. Since the data for both E [Y_{i0}|D_i=0] and E [Y_{i0}|D_i=1] are available, then the ATT can be obtained by comparing the means of those two groups.

To get the treatment effect, the propensity for drinking alcohol was estimated using probit regression. To control for the heterogeneity, a large set of variables are chosen. However, there is a controversy in the literature regarding which variables should be contained in the propensity score estimation model. Rubin et al. (1996) advocated that all covariates which are likely to be associated with an outcome should be included in a propensity score estimation model. Heckman et al.(1997) suggested that ignoring covariates which determine participation status and outcome simultaneously can lead to biased estimates. More recently, Dehejia and Wahba (1999) pointed out that variables which influence both treatment variables and outcome variables should be included in an estimation model. Six categories of variables which are chosen to estimate the propensity score are mainly based on the previous literature.

Once the propensity scores are obtained through estimation, each individual in the treated group is matched with one or more individual that has a similar propensity score in the control group. Theoretically, all matching estimators asymptotically converge when the sample is large enough. However, the choice of the matching method is important when the sample is small (Heckman et al.1997). Several estimators, including the nearest neighbor matching estimator (the default estimator), the caliper matching estimator, the kernel matching estimator and the Mahalanobis matching method are used in this study. Simultaneously, using various matching techniques will contribute to investigating the sensitivity of the results to the employed algorithm.

Since matching estimators are based on the assumption of "selection on observable," which cannot be attested, selection bias caused by unobserved characteristics cannot be addressed by the matching estimators and regression methods. For instance, less motivated adolescents with lower educational aspirations are self-selected to drink alcohol and are tired of school, and thus drop out. If true, the positive relationship between early alcohol use and dropout rates would not necessarily reflect a causal effect of drinking. In fact, it is impossible to include all relevant covariates in one model. In addition, Woodbridge (2005) argues that CIA generally fails if the covariates themselves are affected by the treatment. For these reasons, Rosenbaum bounds technique is used to test the results' robustness to the unobservable characteristics.

2.4 Data and variable definitions

The data source for this analysis comes from National Longitudinal Survey of Youth 1997(NLSY97). It consists of a nationally representative sample of youths who were aged between 12 and 16 as of December 31, 1996. The data contains extensive behavior information on educational experience, family background information, and alcohol use information. Compared with the NLSY79 data set, the information provided by NLSY97 is more reliable, since computer assisted personal interviewing systems are used to lower the possibility of inconsistent data. Also, it is less likely for respondents to suffer from recall bias. Twelve rounds [9]of data have been released since 1997 when 8,984 individuals were interviewed. The retention rate is about 85 percent. As the focus of this paper is on the relationship between teen drinking and high school dropout status, observations with missing important information are excluded from the analysis. Therefore, after accounting for the missing data and reporting errors, the number of observations used in this study is 4,029[10], including 50 percent male and 58 percent white teenagers.

The key dependent variable used in the analysis is the dropout condition variable. Data from wave twelve are used to determine whether or not a respondent is a high school dropout given the fact that the youngest respondent had reached the age of 24 by 2008 by which time a student should has completed high school education. Generally, a student who did not receive his/her high school diploma is identified as a high school dropout. However, controversial issues arise when dealing with the General Educational Development (GED) certificates. Although a GED credential is considered equivalent to a high school diploma, the equivalency between those two has been questioned by some scholars. Cameron and Heckman (1993) demonstrated that GED

[9] The first wave of data was collected in 1997 and the last wave (12th wave) was collected in 2008.

[10] The sample is still representative of the target population since the fluctuation of the percentages of male and white is very small in comparison with data obtained from each round.

receivers are essentially similar to high school dropouts. Quinn (2009) showed that the initial mission of the GED shifts yearly. Approximately 700,000 high school dropouts tried to be certified as "high school equivalent" through the GED program. Consistent with these literatures, the GED holders are considered as high school dropouts in this analysis. Thus, youngsters who fail to complete school and obtain a GED certificate are deemed as dropouts and coded as "1," the rest who are considered graduates are coded as "0."

The key independent variable of interest is the measure of drinking status. Since adolescent alcohol consumption is illegal in the U.S. and the focus of this study is effect of early drinking onset, the level of drinking is not differentiated in this study. Teen drinking status is judged by a binary indicator which is based on the response to the following questions: "Have you ever drunk alcohol?" This question has been asked six times since 1997. The data of the first four waves are used in the analysis. A respondent is defined as an early drinker if he provides a positive response to this question; otherwise, he will be considered a non-drinker. To eliminate the simultaneity and reverse causality between drinking and dropout rates, the respondents who drop out of school before drinking occurs will be excluded from the analysis.

The choice of independent variables is primarily based on existing literature, although little guidance can be found in the literature. Given adolescence is a particular and important period for a person who begins to interact more with other peers and society, I added social behavior variables and peer influence variables , which are rarely used in existing literature. Omitting these relevant variables is likely to result in spurious relationships between alcohol drinking and dropout rates, given the fact that the attitude of adolescents toward schooling and alcohol consumption are also likely to be influenced by their peers and their school experience.

Variables used in this study fall into six categories. Demographic variables include the age, gender and race of the respondents. Family background variables include indicators of whether or not a respondent received income from jobs last year, lives with his parents, and is economically independent. It also includes variables on whether or not a respondent's parents received income last year and the number of years of schooling of a respondent's parents. Health status variables include indicators reflecting a respondent's health status and his/her parent's health status. Social behavior variables reflect a respondent's attitude towards schooling which includes indicators whether or not the respondent cheated in exam, fought at school, felt safe at school, whether or not a respondent has carried a gun, and other drug use information including whether or not a respondent smokes or uses marijuana. Peer influence variables reflect whether or not the peers of a respondent consume alcohol. To satisfy the balancing property of PSM, three interaction terms are also added into the estimation models. For the variables which assume percentage values, I set the median value (50%) as the cutoff value. If a specific value is greater than the cutoff value, then it is coded as 1, otherwise 0.

The summary statistics, including means and standard deviations, for each variable by gender and region, are listed in Table 1. The dropout rate for adolescent males is 15 percent which is higher than that of adolescent females. The dropout rates [11] are consistent with the results reported by Lahey (2003). The urban adolescent drinking rate is a bit higher than that of rural adolescents. Table 1 shows that more respondents in rural areas are white, more independent, and more likely to feel safe at school. In contrast, urban adolescents are more inclined to use marijuana. Table 1 also demonstrates some gender differences. For example, male

[11] However, this rate is a bit higher than the rate reported by the U.S. Department of Education, since the people with GED are considered high school graduates.

adolescents are more likely to have carried guns and have fought at school than female adolescents. However, female youths are more likely to have cheated in exams.

2.5 Empirical Results

Table 2 gives the results of propensity scores and pseudo R-square from probit regression. Pseudo R-square reveals how well the covariates *X* explain the drinking probability. The pseudo R-square demonstrates that the model explains adolescent females' drinking probability better than that of adolescent males. The findings demonstrate that several factors significantly influence the teenage alcohol consumption in all four groups. Three common factors consistently and significantly affect early alcohol abuse positively. Having a history of using marijuana or smoking cigarettes positively and significantly affects early alcohol use. More importantly, using marijuana appears to demonstrate the strongest association with the possibility of adolescent alcohol use. Interestingly, using marijuana and smoking cigarettes significantly lowers the possibility of drinking in urban regions, but these effects are not statistically significant to the rural adolescents. As expected, the age of a respondent is significantly positively associated with alcohol consumption.

Male adolescents who grow up in urban areas are more inclined to drink alcohol early if they are white or have carried a gun. This is reflected by the positive significant signs of the coefficient of those variables in the urban estimation equation. However, the coefficients of those two variables are not significant in the female estimation equation. Working while in school is positively associated with drinking alcohol. Peer drinking influence affects adolescents' drinking in all regions. These effects are stronger and significant in the case of urban adolescents. Rural female adolescents living with their parents are significantly less likely to abuse alcohol.

However, this effect on the other groups is dim and insignificant. Counter to expectations, parents' education levels are positively related to drinking behavior.

Once the propensity scores are obtained from the estimation of the probit model, I proceeded to perform the matching. Since the performance of disparate matching techniques relies primarily on the data structure at hand, there is no consensus on the best strategy. In light of the lack of consensus on this issue, four alternative matching techniques, including nearest neighbor matching (default), caliper matching (r = 0.1 and 0.05), kernel matching (bandwidth = 0.5), and Mahalanobis matching, are implemented in this analysis to test the model's sensitivity, and the results are compared. The standard error of each matching estimator is obtained using bootstrapping methods. The most straightforward way is the nearest neighbor matching method. Compared with nearest neighbor matching, caliper matching excludes the possibility of bad matches, especially when r is small. Kernel matching weighs all the observations with the common support. Mahalanobis metric matching is a combination of the Mahalanobis matching and estimated propensity score, both of which are used to calculate the Mahalanobis distance.

Table 3 presents the matching results. Bold numbers and asterisks display statistically significant effects. The effects of early alcohol abuse are identified as the changes in average dropout rates between treated and control groups. As expected, the results in the table show that different matching techniques produce disparate ATTs and the generated effects are more consistent for the rural adolescents than the urban youths. I do not find a consistent effect of drinking on the high school dropout rate for urban youths, but I do find consistent effects on rural youths. An examination of the lower panel reveals that there is a significant causal impact between rural male youth drinking and high school dropout status. For rural male teenagers, alcohol drinking early raises the high school dropout rate significantly by 5 percent. In contrast, early teenage drinking has no significant effect on female high school dropout rate.

Early drinking's impact on urban adolescents is not as evident as that on the rural youngsters. Results from the upper panel show that the causal relationship is inconclusive. Various estimators produce essentially different outcomes. Interestingly, Mahalanobis matching technique produces a counterintuitive result that teen drinking will contribute to lowering the high school dropout rate for urban female youngsters. Although this result appears a bit unexpected, it is not too surprising. As mentioned earlier, the level of drinking is not differentiated in this study. One possible explanation for this result is that drinking habits may be different between boys and girls. However, most estimators reflect a positive association between early alcohol drinking and high school dropout rates.

An important issue in the matching process is to check the common support assumption. Adding the common support restriction can ensure that both control and treatment groups share common observed characteristics and produce credible estimates in the matching process. The most straightforward way to do this is to draw the density distribution of the propensity score of both treated and control groups. The results can be found in Figure 1. It can be seen from any of the four figures that there is a strong overlap in the middle range of the propensity score, while the distribution of untreated respondents are left skewed and that of the treated respondents are right skewed. The minima and maxima criterion is used in this analysis and the respondents outside of the common support regions are deleted from the sample and not used in the estimation of ATT. The common support graphs in Figure 1 demonstrate that there are good overlaps of propensity scores in every examination group.

Another important issue is to check whether the covariates in the treated group and control group are identically distributed. Matching can yield reliable results only if the significant difference of covariates among alcohol users and nonusers are eliminated. Balancing property[12] is checked using the stratification test (Dehejia and Wahba, 1999, 2002). The sample is split into several strata at the beginning. For each stratum, a two-sample t-test is implemented to test if the distribution of the explanatory variables is equal. If the test fails, the stratum will be split and t-tests are conducted again. Once the t-test passes, then we are confident that the balancing property[13] is satisfied.

The estimated ATTs so far depend on the validity of the "selection on observables". However, if there are some unobserved characteristics which also affect receiving the treatment, the drinking effects could be altered by them. To account for this hidden bias, Rosenbaum bounds analysis is conducted to explore whether the inference about drinking effects may be altered and whether the matching estimators are robust to the unobserved characteristics which potentially affect the selection into the treatment.

This approach begins with the formulation of the propensity score which is not only determined by the observed characteristics, but also the unobserved factor u_i :

$$\pi_i = \Pr(D_i=1|X_i, u_i) = F(\alpha X_i + \beta u_i)$$

where α, β are unknown parameters and β is the effect of u_i on the probability of drinking. If we assume function F is logistically distributed, then the odd-ratio between respondent i and

[12] Other Methods including Standard Bias (SB) (Rubin and Rosenbaum, 1985), pseudo R-square (Sianesi, 2004) can also be used to confirm the balancing property.
[13] The detailed results cannot report here due to space consideration but are available upon request.

respondent j is $\pi_i(1\text{-}\pi_j)/\,\pi_j(1\text{-}\pi_i)$ which equals to $e^{\beta(u_i-\,u_j)}$(Rosenbaum,2002). Therefore, even if respondent i and respondent j have similar observed characteristics, unobserved factors make the probability of drinking different between those two respondents. Basically, I increase e^{β} to see whether the inference based on the test statistic is altered. Following previous literature, Mantel and Haenzel's (1959) test statistic is used in this study.

The results of the sensitivity test based on the default estimator are demonstrated in Table 4. For the rural male group, the magnitude of e^{β}, which turns a statistically significant estimate into an insignificant one, are identified. This methodology also allows us to find the magnitude of e^{β}, which turns a statistically insignificant estimate into a significant one in the other three groups. e^{β} equals 1 which means that there is no hidden bias. A critical value of e^{β} equals approximately 1.1 represents a scenario assuming that a respondent with the same covariates X would be different in the odds of drinking by 10 percent. $e^{\beta} > 1$ does not only imply the existence of unobserved factors, but also the nonexistence of treatment effect (Becker and Caliendo, 2007).

For rural male adolescents, findings above already show that ATT is positive and significant under the assumption of no unobserved heterogeneity. As e^{β} increases, we can find the critical value of e^{β} lies between 1.05 and 1.1 which makes this effect into insignificant. The small critical value implies that the finding of a positive ATT is very sensitive to small changes in unobserved factors.

For the other three groups, since the ATTs are not significant, Rosenbaum bounds analysis helps me find the critical value of e^{β}, which turns an insignificant ATT into a significant one. When the critical value of e^{β} increases to 1.5(1.6), the ATT becomes significant for urban adolescent males (females). For rural female adolescents, this critical value is even higher.

2.6 Conclusion

This paper is in an attempt to examine the effect of early teen drinking on subsequent high school dropout rates. The results lend some support to the claim that youth drinking is harmful to educational outcomes and highlight some interesting regional and gender differences. However, we should treat these results with some caution.

The findings demonstrate that there is a significant and positive causal relationship between rural male adolescent drinking and high school dropout rates. For the other three groups, the causal relationship is insignificant. In particular, this positive causality is questioned when it comes to the urban female group. The findings also show that the rural high school dropout rate is affected by the early intake of alcohol. As for gender differences, the findings show that male adolescents are more likely to become the victims of alcohol abuse than female adolescents.

The results of this study further our understanding of whether or not there is a causal relationship between early alcohol drinking and high school dropout rates and to what extent alcohol consumption affects high school dropout rates in urban and rural regions. A unique contribution of this study is that it takes both regional and gender difference into account. Moreover, PSM provides credible and accurate results that are useful to educators and policy makers. Obviously, one policy implication from this analysis is that concerted effort should be made to limit access to alcohol for adolescents, especially rural males.

This study also contributes to the literature in that this is the first study to explore this causal relationship using the NLSY97 data, the results of which are supposed to provide a good comparison and complement to the previous literature and more timely insights to the policymakers.

Table1. Summary Statistics of Variables

	Urban		Rural	
Variable	Male	Female	Male	Female
Dropout condition	0.15	0.10	0.13	0.10
	(0.36)	(0.30)	(0.34)	(0.30)
Drinking condition	0.45	0.45	0.42	0.40
	(0.50)	(0.50)	(0.49)	(0.49)
Age	14.91	14.97	14.94	15.01
	(1.39)	(1.37)	(1.39)	(1.41)
White	0.56	0.50	0.76	0.77
	(0.50)	(0.50)	(0.43)	(0.42)
Health condition	0.78	0.70	0.82	0.73
	(0.41)	(0.46)	(0.38)	(0.45)
Parent's health condition	0.64	0.61	0.66	0.62
	(0.48)	(0.49)	(0.47)	(0.49)
Parents income	0.79	0.80	0.79	0.83
	(0.40)	(0.40)	(0.41)	(0.38)
Independent	0.03	0.03	0.01	0.01
	(0.17)	(0.16)	(0.12)	(0.12)
Earn income	0.50	0.49	0.56	0.51
	(0.50)	(0.50)	(0.50)	(0.50)
Feel safe at school	0.86	0.85	0.90	0.90
	(0.34)	(0.35)	(0.30)	(0.29)

Fight at school	0.21	0.09	0.21	0.08
	(0.41)	(0.28)	(0.40)	(0.27)
Cheat in exam	0.56	0.64	0.53	0.64
	(0.50)	(0.48)	(0.50)	(0.48)
Use marijuana	0.21	0.21	0.18	0.15
	(0.41)	(0.40)	(0.38)	(0.36)
Smoke	0.39	0.39	0.39	0.41
	(0.49)	(0.49)	(0.49)	(0.49)
Carry a gun	0.15	0.03	0.18	0.02
	(0.36)	(0.18)	(0.39)	(0.14)
Father's education	13.12	12.94	12.74	12.42
	(4.99)	(3.21)	(2.64)	(2.75)
Mother's education	13.14	12.95	12.87	12.80
	(4.16)	(2.96)	(2.40)	(2.51)
Live with parents	0.60	0.58	0.69	0.65
	(0.49)	(0.50)	(0.46)	(0.48)
Smoke* use marijuana	0.18	0.18	0.17	0.14
	(0.38)	(0.39)	(0.37)	(0.35)
Father education* mother education	177.61	173.44	167.58	162.87
	(87.96)	(69.68)	(58.52)	(58.13)
Income * race	0.33	0.31	0.46	0.45
	(0.47)	(0.46)	(0.50)	(0.50)

Peer drinking	0.51	0.62	0.49	0.60
	(0.50)	(0.48)	(0.50)	(0.49)

Table 2. Probit Regression Results

Variable	Urban		Rural	
	Male	Female	Male	Female
Age	0.10***	0.14***	0.18***	0.26***
	(0.03)	(0.04)	(0.06)	(0.06)
White	0.26**	0.11	0.40*	0.29
	(0.11)	(0.12)	(0.22)	(0.22)
Health condition	-0.05	-0.02	-0.05	-0.04
	(0.09)	(0.09)	(0.17)	(0.15)
Parent's health condition	0.06	-0.07	-0.17	-0.15
	(0.09)	(0.08)	(0.15)	(0.14)
Parents income	0.05	0.11	-0.18	0.30*
	(0.09)	(0.10)	(0.16)	(0.18)
Independent	0.08	0.19	-0.78	-0.84
	(0.25)	(0.28)	(0.53)	(0.59)
Earn income	0.10	0.14	0.75***	0.50*
	(0.11)	(0.12)	(0.26)	(0.30)
Feel safe at school	0.14	0.13	0.02	0.02
	(0.11)	(0.12)	(0.22)	(0.24)
Fight at school	0.08	0.21	0.20	0.19
	(0.10)	(0.15)	(0.17)	(0.24)
Cheat in exam	0.11	-0.02	-0.05	0.20
	(0.08)	(0.08)	(0.13)	(0.14)

Use marijuana	1.88***	1.72***	0.64	1.66**
	(0.26)	(0.30)	(0.69)	(0.79)
Smoke	0.83***	1.07***	1.06***	1.04***
	(0.09)	(0.09)	(0.14)	(0.14)
Carry a gun	0.38***	-0.08	0.08	-0.01
	(0.11)	(0.26)	(0.17)	(0.53)
Father's education	0.02	-0.006	0.08	0.27**
	(0.03)	(0.04)	(0.09)	(0.12)
Mother's education	0.01	0.03	0.21**	0.22*
	(0.03)	(0.04)	(0.10)	(0.11)
Live with parents	0.09	-0.07	-0.08	-0.36***
	(0.08)	(0.08)	(0.14)	(0.14)
Smoke* use marijuana	-0.86***	-0.81**	0.33	-0.65
	(0.30)	(0.33)	(0.73)	(0.83)
Father education* mother education	-0.001	0.0004	-0.01	-0.02**
	(0.002)	(0.003)	(0.01)	(0.01)
Income * race	0.02	-0.15	-0.48	-0.17
	(0.15)	(0.16)	(0.30)	(0.34)
Peer drinking	0.35***	0.64***	0.23	0.12
	(0.09)	(0.10)	(0.16)	(0.16)
PseudoR2	0.29	0.35	0.31	0.35

*** Statistically Significant at P<0.01

** Statistically Significant at P<0.05

Table 3. Matching Results

Urban	Male				Female			
	ATT	Standard error	Treated number	Control number	ATT	Standard error	Treated number	Control number
NNM	0.024	0.020	660	804	0.018	0.016	648	806
Caliper(r=0.05)	0.022	0.020	660	804	-0.004	0.018	648	806
Caliper(r=0.1)	0.018	0.019	660	804	0.002	0.017	648	806
Kernel	0.016	0.021	660	804	0.009	0.018	648	806
Mahalanobis	-0.006	0.035	660	804	-0.098***	0.033	648	806

Rural	Male				Female			
	ATT	Standad error	Treated number	Control number	ATT	Standard error	Treated number	Control number
NNM	0.055**	0.033	236	322	0.026	0.029	223	330
Caliper(r=0.05)	0.059**	0.031	235	322	0.009	0.028	223	330
Caliper(r=0.1)	0.057**	0.031	236	322	0.010	0.028	223	330
Kernel	0.052**	0.028	236	322	0.015	0.027	223	330
Mahalanobis	0.051***	0.029	236	322	0.017	0.054	223	330

**significant at 5 percent level and ***significant at 1 percent level.

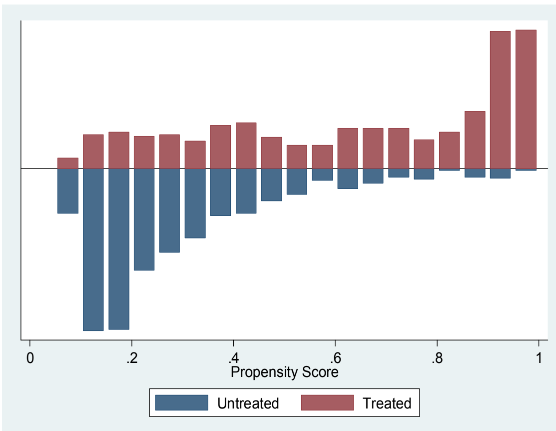
Table 4. Sensitivity Analysis Test for Hidden Bias

Urban				Rural			
Male		Female		Male		Female	
e^{β}	p-value	e^{β}	p-value	e^{β}	p-value	e^{β}	p-value
1	0.13	1	0.16	1	**0.06**	1	0.22
1.1	0.31	1.1	0.31	1.05	**0.09**	1.05	0.27
1.2	0.52	1.2	0.49	1.1	**0.12**	1.1	0.32
1.3	0.33	1.3	0.41	1.15	0.16	1.15	0.37
1.4	**0.18**	1.4	0.26	1.2	0.20	1.2	0.42
1.5	**0.08**	1.5	**0.16**	1.25	0.25	1.25	0.47
1.6	0.04	1.6	**0.09**	1.3	0.30	1.3	0.52
1.7	0.01	1.7	0.05	1.35	0.35	1.35	0.55
1.8	0.00	1.8	0.02	1.4	0.40	1.4	0.51
1.9	0.00	1.9	0.01	1.45	0.45	1.45	0.46
2.0	0.00	2.0	0.00	1.5	0.51	1.5	0.42

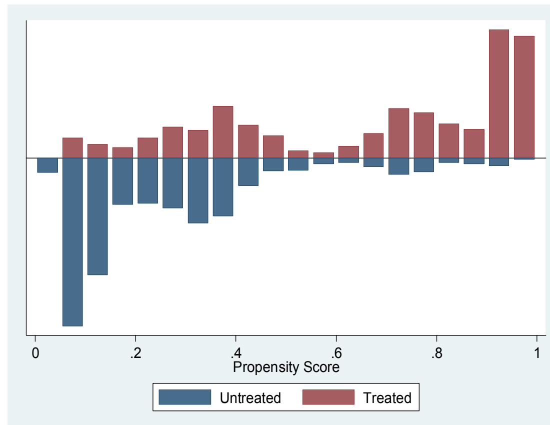
*p-critical value is 0.10

Figure 1. Distribution of propensity score for each group

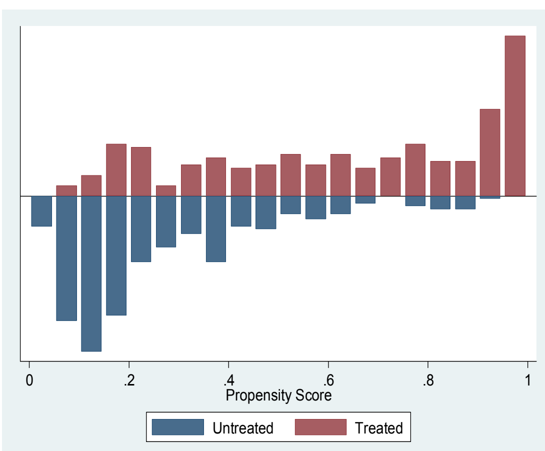
Urban Male



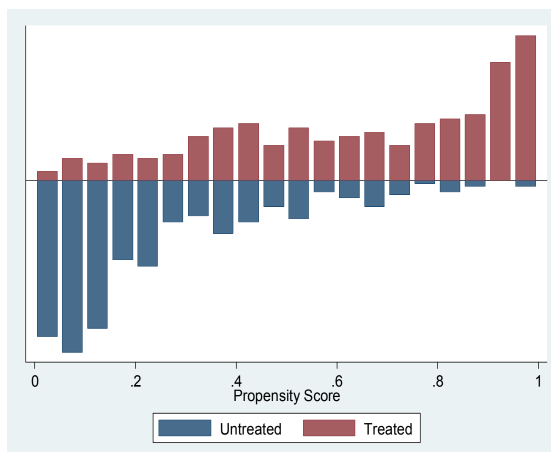
Urban Female



Rural Male



Rural Female



Chapter 3 CO_2 emissions, Electricity consumption and Economic growth: Evidence from a panel of Sub-Sahara African Countries

3.1 Introduction

Although Sub-Saharan Africa is abundant in energy resources, it has the lowest electrification rate in the world, varying from 70% in South Africa to as low as 6% in Mozambique. It is widely acknowledged that energy, especially electricity is critical to SSA countries' prosperity, so that lack of electricity access is still the main problem faced by many SSA countries in their economic development. Although SSA countries only consume a small fraction of electricity used by developed countries, urbanization and economic growth will make SSA countries achieve the energy transition from traditional wood fuel to ultimate electricity. In recent years, due to economic growth and government program supports, electricity access has been expanded much more in some SSA countries. For example, electricity is more widely used in Botswana than it was a decade ago. The "World Economic Outlook" (2008) projected that the electricity demand will be doubled by 2030 due to the increase in population and income in developing countries. It is estimated that SSA countries' increase of the consumption of electricity, which is related to the increase of the expected growth, may affect the climate changes.

Recently, world-wide concerns increase with regard to the global warming and climate changes caused largely by greenhouses' gases, especially the carbon dioxide emissions which account for 58.8% of the total emissions (World Bank, 2007). According to IEA (2010), CO_2 emitted from the generation of the electricity and heat covers 41% of the world total CO_2

emissions. SSA countries' contribution to CO_2 emissions is low in both absolute and per capita terms, and its total CO_2 emissions account for 3.6% of the total world's CO_2 emissions in 2007. Compared with the amount of the per capita emission in 1950, the per capita CO_2 emissions increased three times to 0.33 metric tons which was only 6.4 % of that of North America. However, SSA countries are vulnerable to the climate change due to its weak capacity to react and adapt. To provide the people in SSA with more electricity access, carbon emission associated with the power consumption would be devastating. The disasters caused by the greenhouse gases will have much more negative impact on the SSA countries given the continuous increase in CO_2 emissions in SSA countries.

There has been a recent surge in the literature which investigates the nexus among CO_2 emissions, energy consumption and economic growth (Ang, 2007, 2008; Apergis and Payne, 2009, 2010; Sadorsky, 2009; Soytas and Sari, 2009; Pao and Tsai, 2010; Lean and Smyth, 2010). This literature is a combination of energy consumption growth literature and EKC hypothesis literature. Energy consumption growth literature investigates the causal relationship between economic growth and energy consumption in which bi-variate models are often considered insufficient and biased. To address this issue, other variables such as labor and capital are usually introduced into the model. Similarly, another strand of analysis based on the EKC hypothesis that assumes as income increase the environment will degrade until the income reaches a threshold level, after which the environmental degradation will decrease as income increase is often deemed as suffering from the omitted variable problem as well. A combined research approach not only contributes to finding dynamic relationships among these three key factors but also help us to solve to the omitted variable problems, which exist in both the bi-variate electricity consumption growth literature and the EKC hypothesis literature. It is also anticipated that such an approach will provide more insights for policy-makers in the SSA countries.

The purpose of this study is to investigate the potential causal relationship between CO_2 emissions, electricity consumption and economic growth in a group of 15 SSA countries. A literature search indicates that there has been no study done under the African context. Therefore, this is the first study which extends the current literature by exploring these relationships in the case of African countries. Based on the most recent panel conintegration model technique proposed by Pedroni (2000, 2004) and the panel vector error correction model, the findings show that the EKC hypothesis does not hold in the African countries' case. The findings also reveal that, in the short run, uni-directional causality runs from electricity CO_2 emissions to output and output to electricity consumption, while there are long-run bidirectional causality between electricity consumption and CO_2 emissions and uni-directional causality running from GDP to electricity consumption and CO_2 emissions.

The rest of the paper is organized as follows. The next section provides a brief literature review. The third section provides a concise description of data sources. The methodology and empirical results are presented in the fourth section. Thereafter, the policy implications of the results are discussed in the fifth section. And the final section summarizes and concludes the paper.

3.2 A brief literature review

There are three branches of recent studies exploring causal relationships between CO_2 emissions, electricity consumption, and economic growth. The first branch focuses on the link between electricity consumption and economic growth. Although the causality between electricity consumption and economic growth has been well investigated in the past two decades since Kraft and Kraft (1978), the results are still divergent due to the disparity on the choice of countries, study periods, variables, and econometric approaches. Four possible relationships, which have been emphasized in existing studies, are growth hypothesis, conservation hypothesis, neutrality hypothesis, and feedback hypothesis. The growth hypothesis asserts that electricity consumption plays a key role in economic growth. Therefore, GDP will change corresponding to the changes in electricity consumption (Shiu and Lam 2004; Tang, 2008; Akinlo, 2009). The conservation hypothesis, where causality runs from GDP to electricity consumption, argues that electricity conservation policies might have little effect on economic growth (Ghosh, 2002; Mozumder and Marathe, 2007). The neutrality hypothesis suggests there is no causality between electricity consumption and economic growth, and thus electricity consumption's impact on economic growth is negligible (Murray and Nan, 1996; Chen et al., 2007). The feedback hypothesis, which suggests a bidirectional causal relationship between electricity consumption and economic growth, highlight the inter-link between them (Jumbe, 2004; Narayan and Smyth, 2009; Odhiambo, 2009).

The second branch studies the relationship between CO_2 emissions and economic growth that initially relies on the EKC hypothesis, indicating an inverted U-shaped connection between environmental demotion and economic development. Like the first branch of studies, although a number of studies have been carried out to test the validity of the inverted U-shaped relationship between green gasses emission and income, the results regarding the existence of the EKC are still inconclusive (For example, Foccali, 2005; Coondoo and Dinda, 2008).

The third, and latest, branch associates the first two branches and explores the nexus in CO_2 emissions, electricity (energy) consumption, and economic growth within a multivariate system. Most of the studies in this group focus on energy consumption (Ang, 2007, 2008; Apergis and Payne, 2009, 2010; Halicioglu, 2009; Soytas and Sari, 2009; Pao and Tsai, 2010), with the exception of the study of Lean and Smyth (2010) focusing on electricity consumption. The causal relationships between those three factors can be determined in a multivariate system and the bias caused by omitted variable problems can be reduced indirectly, however, the directions of the causality still vary due to the difference of the data set and variables, the sample length, and the target countries. The relevant previous studies are summarized in Table 1.

In spite of the fact that there has been a large amount of studies addressing the relationship between electricity consumption and economic growth, there is a dearth of evidence for SSA countries. To the best of my knowledge, only a few of them address this problem in an African context (Wolde-Rufael, 2005, 2006, 2009; Akinlo, 2008; Kebede et al., 2010). These studies, using short time span of data [14]and focusing on a single country, often suffer from the omitted variable bias due to relevant variable omission. Also, these studies are often hampered by the methodological constraints which may undermine the credibility of the policy implication. Moreover, none of these studies investigate the causality between electricity consumption, CO_2 emissions and economic growth in a combined approach. In contrast with the existing literature, the present study fills this gap using the most recent panel techniques to address these issues in a multivariate model.

[14] Unit root tests and cointegration tests can be distorted when the time series is short (Campell and Perron, 1991).

3.3 Data and model

The empirical analysis uses annual data for a panel of 15 SSA countries (Benin, Brunei Darussalam, Cote d'Ivoire, Cameroon, Congo, Rep., Congo, Dem. Rep., Gabon, Ghana, Kenya, Nigeria, Mozambique, Sudan, Senegal, South Africa and Zambia) on their CO_2 emissions, electricity consumption, and GDP over the period of 1980-2007. The sample, which is restricted to these 15 countries, is based on the availability of the data on the variables included in this study. Annual data on electric power consumption (E) (kWh), CO_2 emissions (C) (kt), and GDP(Y) (constant 2000 US$) were obtained from World Bank indicator (2011). All variables are converted into natural logarithms before analysis.

Following the approach first proposed by Ang (2007) in the empirical literature, we can form the long-run relationship among CO_2 emissions, electricity consumption, and economic growth in the panel data framework as follows:

$$LC_{it}=\beta_{it}+\beta_{1i}LE_{it}+\beta_{2i}LY_{it}+\beta_{3i}LY_{it}^{2}+\varepsilon_{it} \qquad (1)$$

where i=1, …, I denotes the country and t=1, …, T refers to the time period. LC_{it} , LE_{it} and LY_{it} represent natural logarithms of CO_2 emissions, electricity consumption, and GDP respectively. The sign of the coefficient β_{1i} should be positive since increased electricity consumption would increase the CO_2 emissions. Under the EKC hypothesis, the sign of β_{2i} is expected to be positive while the sign of β_{3i} is supposed to be negative, which reflects the inverted U-shape curve between CO_2 emissions and GDP. Lastly, ε_{it} that is assumed to be independent and identically distributed (I.I.D.) is the estimated residual.

3.4 Econometric analysis and results

The major goal of this empirical study is to examine the existence and direction of the causal relationship between CO_2 emissions, electricity consumption, and economic growth in the 15 SSA countries. The second objective is to find the long-run relationship between CO_2 emissions, electricity consumption, and economic growth. A three-step procedure is adopted in this analysis. To begin with, panel unit root tests are used to examine a unit root for each variable. Secondly, panel cointegration tests are applied if the variables have a unit root. Finally, panel cointegration tests are utilized to find the causality between these three variables.

3.4.1 Panel unit root tests

Consistent with the existing literature, the empirical analysis starts with the examination of the stationary property of the included variables using panel unit root tests. The advantage of panel unit root tests over unit root tests is that pooling information across units increases the test power. To check the robustness of the results five panel unit root tests-including the LLC test, the Breitung test, the IPS test, and the Fisher-type tests are applied in this study.

The LLC test proposed by Levin et al. (2002) is based on the following equation:

$$\Delta x_{it}=\alpha_i+\beta x_{i,t-1}+\sum_{j=1}^{p_i}\beta_{ij}\Delta x_{i,t-j}+u_{it} \qquad (2)$$

where i=1, …, I denotes the country and t=1, …, T refers to the time period and $x_{i,t}$ is the series for country i over the time period t. The number of lags is determined by p_i and the residual u_{it} is hypothesized to be I.I.D. The null hypothesis of the LLC test is H_0: β=0 against the alternative H_1: β<0.

Like the LLC test, the IPS test proposed by Im et al. (2003) is also based on equation 2 but in the IPS test β can vary across countries. The IPS test is superior to the LLC test in that it allow for heterogeneity for the coefficient of β for all panel units. The null hypothesis of the IPS test is H_0: $\beta_i=0\ \forall i$, while the alternative hypothesis is H_1: $\beta_i<0\ \forall i$.

Following Fisher (1932), Maddala and Wu (1999) proposed the Fisher-type tests by combining the p-values from individual unit root tests. It solved the cross correlation problem existing in the IPS test. The non-parametric test statistic is $\Lambda=-2\sum_{i=1}^{N}\ln p_i$ where p_i is the p-value for each individual unit root test. Maddala and Wu (1999) demonstrate the superiority of the Fisher-type tests using the Monte Carlo simulation.

The Breitung (2000) panel unit root test states that panel data y_{it} is formulated as $y_{it}=\alpha_i+\beta_i t+u_{it}$ where the error term follows $u_{it}=\rho_i u_{i,t-1}+\epsilon_{it}$. To test the presence of a unit root in all cross-sectional units, we need to test the null hypothesis of H_0:$\rho_i=1\ \forall i$. According to Hlouskova and Wagner (2006), the Breitung test has the highest power and smallest size distortions relative to the other tests, thus our results are based on this test.

The results of the panel unit root tests for the series of CO_2 emissions, electricity consumption and GDP using the above-mentioned approaches are reported in Table 2. The panel unit root tests show that the results for the level variables are mixed from disparate tests. Take LC as an example, some tests (LLC, Breitung) demonstrate that it contains a unit root while other tests (IPS, ADF-Fisher) reveal no evidence of a unit root. If there is cross-sectional dependence across countries, the first generation panel unit root tests will show large size distortions (Maddala and Wu, 1999; Strauss and Yigit, 2003). Since conventional panel unit roots cannot address the issue of cross-sectional dependence, so they tend to reject the nonstationary hypothesis too often. In order to address the problem of cross-sectional dependence, cross-sectionally dependent panel unit root test[15] (CIPS) which was proposed by Pesaran (2007) was also applied. Pesaran (2007) show this test is more robust to cross section dependence than other tests mentioned earlier. The CIPS test results are also reported in Table 2. Given its superiority, our results are based on the CIPS test. As shown in Table 2, the series for each variable contains a unit root at the 1% level of significance. Taken the fist difference, all these four series are I (0).

3.4.2 Panel cointegration tests

Since all the variables are integrated of order one I (1), the next step is to conduct the panel cointegration test that was proposed by Pedroni (2004). Following Pedroni (2004), to test the conintegraion in a panel data context, we construct the model as follows:

$$LC_{it}=\beta_i+\rho_i t+\beta_{1i}LE_{it}+\beta_{2i}LY_{it}+\beta_{3i}LY_{it}^2+\varepsilon_{it} \quad (3)$$

where i=1, …, I denotes the country and t=1, …, T refers to the time period and β_i and ρ_i are the intercept and deterministic trend specific to each country, respectively. Pedroni (1999) proposed two sets of tests: panel cointegration tests and group mean panel cointegration tests. The former tests, which are based on the within dimension technique, contained four statistics (panel v-statistic, panel ρ-statistic, panel PP-statistic, and panel ADF-statistic), while the latter ones containing three statistics (group ρ-statistic, group PP-statistic, and group ADF-statistic) are based on the between dimension approach. To test the existence of cointegration, the test based on the residual term ε_{it} is conducted as follows:

$$\varepsilon_{it}=\delta_i\varepsilon_{it-1}+u_{it} \quad (4)$$

[15] For a detailed discussion of the CIPS test, see Pesaran (2007).

Table 3 reports the results of Pedroni's (2004) residual panel cointegration tests. The results from these tests are mixed. Except for the panel v-statistic, panel ρ-statistic and group ρ-statistic, the panel cointegration test rejected the null hypothesis that there is no cointegration at the 10% significance level. Given the facts that PP-statistics are more powerful than rho-statistics and more statistics are inclined to reject the null hypothesis, we can confirm that there exist cointegration relationships between CO_2 emissions, electricity consumption, and economic growth.

Pedroni (2000) suggests using the fully modified OLS (FMOLS) estimator since the panel OLS estimator is biased. Pedroni(2001) also indicates that dynamic OLS(DOLS) outperform OLS by eliminating serial correlation and endogeneity. The results from FMOLS and DOLS [16]are reported in Table 4. For each variable, the long-run panel elasticities from both estimation approaches are remarkably similar in sign and magnitude. For SSA countries as a whole, the long-run panel elasticity of CO_2 emissions with regard to electricity consumption is significantly positive which implies that a 1% increase in electricity consumption will increase CO_2 emissions by 0.14% in both estimation techniques which are in line with the results of Ang(2007), Aperigis and Payne(2009), and Smyth and Lean(2010). The long-run panel elasticity of CO_2 emissions with regard to GDP in the FMOLS model can be formulated as $\partial LC/\partial LY$ = -4.44+0.24 LY with the threshold GDP of 18.5(in logarithms) which means that with the increase of total GDP CO_2 emissions will not increase until total GDP reach 18.5. However, the coefficient of LY^2 is positive, which contradicts with the inverted EKC hypothesis. This result is similar to Coondoo and Dinda(2008) where an inverted EKC curve cannot be found for Africa. As a way of

[16] Banerjee(1999) argues that FMOLS and DOLS are asymptotically equivalent when the sample size is large.

comparison, our results are consistent with Foccali (2005) for China, Brazil, and India and Soytas and Sari (2009) both of which did not find the evidence of the existence of the EKC hypothesis. However, our results, which are contrary to Ang (2007) and Apergis and Payne (2009), seems to confirm the validity of the EKC hypothesis.

3.4.3 Panel Granger causality tests

Given the existence of long-run relationship between CO_2 emissions, energy consumption, and economic growth, we proceed to examine the causal relationship among these variables in a panel context. The Engel-Granger two-step test is employed in this analysis. We begin with the estimation of equation 3 and get the estimated residual. Next we estimate a dynamic vector error correction model specified as follows:

$$\Delta LC_{it}=\omega_{1i}+\sum_{j=1}^{q}\theta_{11ij}\Delta LC_{it-j}+\sum_{j=1}^{q}\theta_{12ij}\Delta LE_{it-j}+\sum_{j=1}^{q}\theta_{13ij}\Delta LY_{it-j}+\sum_{j=1}^{q}\theta_{14ij}\Delta LY_{it-j}^{2}+\lambda_{1i}\varepsilon_{it-1}+u_{1it} \quad (5a)$$

$$\Delta LE_{it}=\omega_{2i}+\sum_{j=1}^{q}\theta_{21ij}\Delta LC_{it-j}+\sum_{j=1}^{q}\theta_{22ij}\Delta LE_{it-j}+\sum_{j=1}^{q}\theta_{23ij}\Delta LY_{it-j}+\sum_{j=1}^{q}\theta_{24ij}\Delta LY_{it-j}^{2}+\lambda_{2i}\varepsilon_{it-1}+u_{2it} \quad (5b)$$

$$\Delta LY_{it}=\omega_{3i}+\sum_{j=1}^{q}\theta_{31ij}\Delta LC_{it-j}+\sum_{j=1}^{q}\theta_{32ij}\Delta LE_{it-j}+\sum_{j=1}^{q}\theta_{33ij}\Delta LY_{it-j}+\sum_{j=1}^{q}\theta_{34ij}\Delta LY_{it-j}^{2}+\lambda_{3i}\varepsilon_{it-1}+u_{3it} \quad (5c)$$

$$\Delta LY_{it}^{2}=\omega_{4i}+\sum_{j=1}^{q}\theta_{41ij}\Delta LC_{it-j}+\sum_{j=1}^{q}\theta_{42ij}\Delta LE_{it-j}+\sum_{j=1}^{q}\theta_{43ij}\Delta LY_{it-j}+\sum_{j=1}^{q}\theta_{44ij}\Delta LY_{it-j}^{2}+\lambda_{4i}\varepsilon_{it-1}+u_{4it} \quad (5d)$$

where i=1, …, I denotes the country and t=1, …, T refers to the time period and q is the optimal lag length automatically determined by Schwarz information criteria. Error correction term ε_{it-1} is obtained by estimating the equation 3.

The short-run causality can be identified by testing the significance of the coefficients of the lagged difference terms, while the long-run causality can be identified by examining the significance of the coefficients of the error correction terms in the panel error correction model using the Wald test. In terms of short-run causality in equation 5a, electricity consumption does not Granger cause CO_2 emissions if the null hypothesis $\theta_{12ij}=0$ (for all i and j) is not rejected whereas LY and LY^2 does not Granger cause CO_2 emissions if the joint null hypothesis $\theta_{13ij}=\theta_{14ij}=0$ is accepted. In the case of short-run causality in equation 5b, CO_2 emissions Granger cause electricity consumption if the null hypothesis $\theta_{21ij}=0$ (for all i and j) is rejected whereas LY and LY^2 Granger cause electricity consumption if the joint null hypothesis $\theta_{13ij}=\theta_{14ij}=0$ is rejected. As for equations 5c and 5d, cross-equation restrictions are applied to determine the short-run causality running from either CO_2 emissions or electricity consumption; that is, CO_2 emissions Granger cause LY and LY^2 if the null hypothesis $\theta_{31ij}=\theta_{41ij}=0$ is rejected whereas electricity consumption Granger cause LY and LY^2 if the null hypothesis $\theta_{32ij}=\theta_{42ij}=0$ is rejected. With regard to the long-run causality in equations 5a through 5d, the significance of the coefficient of the error correction terms are tested.

The results of causality tests are presented in Table 5. In the short run, we can find evidence of causality running from CO_2 emissions to GDP, implying that GDP will be influenced by the CO_2 emissions in the SSA countries. We can also find causality running from GDP to electricity consumption, which suggests that with economic growth, electricity consumption will play a more important role in the SSA countries. However, we cannot find evidence of short-run causality running from CO_2 emissions to electricity consumption and vice versa, implying that electricity consumption will not have an impact on CO_2 emissions and it will not be affected by CO_2 emissions as well.

In the long run, the coefficients of error correction terms in both equations 5a and 5b are significant, which imply that CO_2 emissions and electricity consumption could play adjustment factors when the system deviates from the long-run equilibrium path. The results also demonstrate that there are bidirectional Granger causality between CO_2 emissions and electricity consumption and unidirectional Granger causality running from GDP to CO_2 emissions and electricity consumption respectively.

3.5 Discussion and policy implication

In both short and long runs, unidirectional Granger causality running from GDP to electricity consumption implies that the SSA countries are energy-independent economies. GDP growth will stimulate the electricity infrastructure construction and lead to an expansion in electricity demand in industrial and commercial sectors, but not vice versa. This pattern is similar to what has happened in Asia (Chen et al., 2007) and Middle East and North Africa (Narayan and Smyth, 2009) and specifically Wolde-Rufael (2006) for some SSA countries such as Cameroon, Ghana, Nigeria, Senegal, and Zambia. This finding reveals that economic growth in SSA countries could stimulate the development of electricity infrastructures in these countries. This finding also suggests that energy conservation policies will not harm the economic performance of the SSA countries which are less vulnerable to energy shocks that could negatively affect GDP growth. After all, electricity is not the main energy source for most SSA countries. However, electricity conservation policy is not a feasible option given the current situation of lacking of electricity access in the SSA countries. A more practical suggestion is to enhance the electricity efficiency in those SSA countries. For example, for Nigeria and Senegal, electricity efficiency can be enhanced by reducing transmission cost and distribution losses which accounts for 32% and 17% of the output respectively (ECA, 2004).

In the short run, the demotion of the environment causally affects GDP growth. Of course, this does not imply that environment degradation is an inevitable process in economic development. However, this finding reflects the experience undertaken by many developing countries. As noted by Ang (2007), environmental protection measures should be implemented to prevent the human health capital from being adversely affected, thus reducing productivity. Unidirectional Granger causality was found from GDP to CO_2 emissions in the long run. This result, which is consistent with Apergis and Payne (2010) for commonwealth of independent states, makes sense since increases in GDP require electricity consumption and as a result CO_2 emissions increased. However, this result is contrary to Pao and Tsai (2010) for BRIC and Lean and Smyth (2010) for ASEAN, both of which suggest that environment degradation will have a causal impact on economic growth.

The findings also demonstrate that bidirectional causality exists between electricity consumption and CO_2 emissions in the long run. This result is in line with Apergis and Payne (2009, 2010) for six Central American countries and Commonwealth of independent states, but contradicts with Pao and Tsai (2010) which reveals a unidirectional causality running from CO_2 emissions to energy consumption. This conclusion makes sense given the specific characteristics of the SSA countries. Economic growth makes people use the cleaner source of energy (electricity) to substitute the traditional wood fuel. Simultaneously, policy makers should be mindful of CO_2 emissions released by the power plants which are responsible for 41% of world's total CO_2 emissions (IEA, 2010). This bidirectional causality further reiterates the importance of enhancing energy efficiency as mentioned earlier.

3.6 Concluding remarks

This study attempts to explore the causal relationships between CO_2 emissions, electricity consumption, and economic growth for a group of Sub-Sahara African countries from 1980 to 2007 using panel error correction modeling techniques. Compared with the existing studies, a trivariate framework aids us to avoid the bias caused by bivariate analysis when investigating those causal relationships. It has been found that the long-run cointegrated relationship between CO_2 emissions, electricity consumption, and economic growth exist and the inverted U-shape EKC hypothesis is not applicable to the SSA countries' case. Our results demonstrate that both short-run and long-run causality running from GDP to electricity consumption exist. And there is unidirectional causality running from CO_2 emissions to GDP in the short run, while in the long run unidirectional causality runs from GDP to CO_2 emissions. Another important finding reveals that there is bidirectional causality between electricity consumption and CO_2 emissions in the long run.

The major contribution of this study is that it fills the void in the literature by exploring the causal relationship between CO_2 emissions, electricity consumption, and economic growth for the SSA countries. Knowledge of these causal relationships will contribute to the policy makers making corresponding policies to cope with these disentangled issues. One limitation of this study is that the analysis is based on an aggregated level and disaggregated sector energy consumption should be included in future research, since the electricity demand among each sector is different. Another limitation is that only 15 countries are included in the analysis due to the data constraints; perhaps more countries in the SSA region could be added in the future research. Future research should also incorporate urbanization into the study given the specific situation of the SSA countries.

Table1. Empirical studies on the causal relationships between CO2 emissions, electricity consumption, and economic growth.

Author	Period	country	Method	Variables	Results
Ang(2007)	1960-2000	France	*ARDL,VECM*	$C,E\ Y,Y^2$	*Y→C* *Y→E*
Ang(2008)	1971-1999	Malaysia	*ECM*	*Y,E,C*	*C→Y* *Y→E*
Halicioglu(2009)	1960-2005	Turkey	*ARDL*	$C,E\ Y,Y^2,f$	*E↔C* *C↔Y*
Soytas and Sari(2009)	1960-2000	Turkey	*TY, VAR*	*Y,K,E,L,C*	*C→E*
Apergis and Payne(2009)	1971-2004	Central America	*PC,ECM*	Y, Y^2,E,C	*C↔E* *Y→C* *Y→E*
Apergis and Payne(2010)	1992-2004	CW.I.S.	*PC,ECM*	Y , Y^2,E,C	*C↔E* *Y→C* *Y→E*
Apergis et al.(2010)	1984-2007	19 countries	*PC,ECM*	*C,N,R,Y*	*C↔Y* *R↔C* *C↔N*
Pao and Tsai(2010)	1971-2005	BRIC	*PC,ECM*	$C,E\ Y,Y^2$	*C→E* *E↔Y* *C→Y*
Lean and Smyth(2010)	1980-2006	ASEAN	*PC,ECM*	$C,E\ Y,Y^2$	*C→Y* *E→Y*

Notes: $C, E\ Y\ and\ Y^2$ denote CO_2 emissions, electricity (energy) consumption, real GDP and real GDP squared respectively. N, R and f denote nuclear energy, renewable energy and openness ratio respectively. → denotes uni-directional causality and ↔ denotes bi-directional causality. Abbreviations are defined as follows: ARDL: Autoregressive distributed lag procedure, VAR:

Vector autoregressive model, PC: Panel Cointegration, TY: Toda-Yamamoto, ECM: Error correction model, CW.I.S. : Commonwealth of independent states.

Table 2.Panel unit root tests

Variables	LLC	IPS	Breitung	ADF-Fisher	CIPS
LC	-0.60	-1.61**	1.20	44.55**	-2.25
	(0.27)	(0.05)	(0.88)	(0.04)	(0.62)
ΔLC	-5.04***	-9.55***	-6.91***	137.95***	-2.93***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
LE	0.33	-0.28	0.06	34.13	-2.59
	(0.63)	(0.39)	(0.52)	(0.28)	(0.13)
ΔLE	-8.19***	-9.44***	-5.30***	143.22***	-3.79***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
LY	-0.23	-0.57	-0.57	50.43***	-2.70
	(0.41)	(0.28)	(0.28)	(0.01)	(0.06)
ΔLY	-3.79***	-6.76***	-3.62***	103.56***	-3.07***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
LY^2	-0.03	-0.36	-0.36	47.23**	-2.69
	(0.49)	(0.36)	(0.36)	(0.02)	(0.06)
ΔLY^2	-3.80***	-6.70***	-3.58***	102.74***	-3.07***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)

Notes: Time trend and intercept are included in the panel unit root tests. The optimal lags are chosen by Schwarz information criteria automatically. Significance at 1% level and 5% level are denoted with *** and ** respectively.

Table 3. Panel cointegration tests.

	Test statistic	Probability
Panel v-Statistic	-2.35	0.99
Panel rho-Statistic	-0.31	0.38
Panel PP-Statistic	-3.15	0.00***
Panel ADF-Statistic	-1.96	0.02**
Group rho-Statistic	1.25	0.90
Group PP-Statistic	-4.44	0.00***
Group ADF-Statistic	-1.55	0.06*

Notes: The tests are asymptotically normally distributed. Significance at 1% level, 5% level and 10% level are denoted with ***, ** and * respectively.

Table 4. Panel long-run FMOLS and DOLS estimates.

	C	LE	LY	LY^2
FMOLS	44.61**	0.14**	-4.44***	0.12***
R^2=0.90	(2.48)	(2.46)	(-2.89)	(3.61)
DOLS	48.74**	0.14**	-4.79***	0.13***
R^2=0.90	(2.55)	(2.29)	(-2.93)	(3.61)

Notes: t-statistics are reported in parenthesis. Significance at 1% level and 5% level are denoted with *** and ** respectively.

Table 5. Panel Granger causality tests.

Dependent Variable	Source of Causation (independent variables)			
	Short-run			Long-run
	ΔLC	ΔLE	ΔLY and ΔLY^2	ECT
ΔLC	-	2.49	4.23	11.61***
		(0.29)	(0.38)	(0.00)
ΔLE	0.60	-	30.67***	3.57*
	(0.74)		(0.00)	(0.06)
ΔLY and ΔLY^2	10.86**	0.89	-	0.34
	(0.03)	(0.93)		(0.84)

Notes: χ^2 statistic for Wald tests are reported here and the p-value are placed in parenthesis. Significance at 1% level, 5% level and 10% level are denoted with ***, **and * respectively.

Appendix

This section presents the parameters, variables and equations used in the Alabama CGE model.

Index sets used in the model:

A – activities

C – commodities

CM⊂C – commodities which have at least one source of imports (from ROW or from RUS or from both)

CE⊂C – commodities which have at least one destination for exports (to ROW or to RUS or to both)

CNM⊂C – commodities which are not imported

CNE⊂C – commodities which are not exported

CM1⊂C – commodities which have exactly one import source

CE1⊂C – commodities which have exactly one export destination

CM2⊂C – commodities which are imported from both sources

CE2⊂C – commodities which are exported to both destinations

F – factors of production and indirect business taxes

FF⊂F – factors of production

I – institutions

H⊂I – households

G⊂I – government units

HG⊂I – households and government units

FG⊂G – federal government units

SG⊂G – state government units

T – trading regions (FT: rest of world, DT: rest of US)

Aliases:

FF – FFF, C – CC, H – HH , G – GG, FG – FGG, SG – SGG

Parameters

xed(C,T)	Elasticity of demand for world export function
esubp(A)	Elasticity of substitution for production
esubd(C)	Elasticity of substitution (armington) between regional output and imports
esubs(C)	Elasticity of substitution (transformation) between domestic (regional) and foreign demand
esube(C)	Elasticity of substitution (transformation) between row and rus for exports
esubm(C)	Elasticity of substitution (armington) between row imports and rus imports
tm(T,C)	Import tax rate
tb(A)	Indirect business tax rate
ty(G,H)	Household income tax rate
trh(H,HH)	Inter-household transfers
mps(H)	Marginal propensity to save
cwts(C)	Weight of commodity C in the consumer price index
xshift(C,T)	Shift parameter for world export demand function
lambda(C,H)	Subsistence level parameter for Stone-Geary utility function
beta(C,H)	Marginal budget share parameter for Stone-Geary utility function
qg(C,G)	Government consumption
shry(I,FF)	Institutional share of factor income
tbshr(G)	Government unit share of indirect business taxes
sgovbal	Initial state government budget balance
pwm(T,C)	World import price in foreign currency (exogenous)
efac(FF)	Demand elasticity for capital and labor
theta(A,C)	Yield of output C per unit of activity A
ica(C,A)	Quantity of C as intermediate input per unit of activity A
ad(A)	Production shift parameter
del(F,A)	Production function share parameter
rho(A)	CES production function exponent
adel(C)	Armington commodity composite share parameter for production
aq(C)	Armington commodity composite shift parameter
arho(C)	Armington commodity composite exponent
sdel(C)	Armington CET composite share parameter for domestic sales

srho(C)	Armington CET composite exponent
as(C)	Armington CET composite shift parameter
edel(C)	Armington composite share parameter foreign exports
erho(C)	Armington composite exponent for exports
ae(C)	Armington composite shift parameter for exports
mdel(C)	Armington composite share parameter foreign imports
mrho(C)	Armington composite exponent for imports
am(C)	Armington composite shift parameter for imports

Variables

PM(C)	Import price (domestic currency)
XR (T)	Exchange rate
PWE(C, T)	World export price
PE(C)	Export price (domestic currency)
PQ(C)	Composite commodity price
PD(C)	Domestic price of domestic output
PMR (T, C)	Regional price of imported commodities
PER(C, T)	Regional price of exported commodities
PA (A)	Activity price
PVA (A)	Value added price
PX(C)	Producer price
QQ(C)	Quantity supplied to domestic commodity demanders
QM(C)	Quantity of imports
QD(C)	Quantity of domestic output sold domestically
QMR (T, C)	Regional imports
QER(C, T)	Regional exports
QX(C)	Quantity of domestic output
QE(C)	Quanitity of exports
QA(A)	Activity level
QF(FF,A)	Quantity demanded of factor FF by activity A
QINT(C, A)	Quantity of intermeditate use of commodity C by activity A

WF(FF)	Average wage or rental rate of factor FF
YF(I,FF)	Factor income
YH(H)	Gross household income
NYH(H)	Net household income
QH(C,H)	Household consumption
QINV(C)	Investment demand
QIINV(I)	Investment demand by institutions
YFG	Federal government revenue
EFG	Federal government expenditure
YSG	State government revenue
ESG	State government expenditure
QFS(FF)	Factor supply
WALRAS	Dummy variable
IADJ	Investment adjustment variable
IIADJ	Institutional investment adjustment variable
SADJ	Savings adjustment variable
SGADJ	State government spending adjustment variable for quantity purchased
IINCOME	Investment on commodities
WFDIST(FF,A)	Wage distortion factor
INDT(G)	Total indirect taxes
IMAKEQ(I,C)	Make matrix (quantity)
SHIFTFF(FF)	Factor supply equation shift variable
FSAVX	Exports foreign savings
DSAVX	Exports RUS savings
FSAVM	Imports foreign savings
DSAVM	Imports RUS savings
CPI	Consumer Price Index

Equations

Regional foreign import price equation

PMR('FT',CM) = pwm('FT',CM)*(1+tm('FT',CM))*XR('FT');

Regional domestic import price equation

PMR('DT',CM) =pwm('DT',CM)*(1+tm('DT',CM))*XR('DT');

Regional foreign export price equation

PER(CE,'FT') = PWE(CE,'FT')*XR('FT')*(1-te(CE,'FT'));

Regional foreign export price equation

PER(CE,'DT') = PWE(CE,'DT')*XR('DT')*(1-te(CE,'DT'));

World export demand function

QER(CE,T) = xshift(CE,T)*(PWE(CE,T)**xed(CE,T));

Armington import composite equation

QM(CM2) =am(CM2)* (mdel(CM2)*QMR('FT',CM2)**(-mrho(CM2))

+(1-mdel(CM2))*QMR('DT',CM2)**(-mrho(CM2))) **(-1/mrho(CM2));

ROW-RUS import ratio

QMR('FT',CM2)/QMR('DT',CM2) =

((PMR('DT',CM2)/PMR('FT',CM2))*(mdel(CM2)/((1-mdel(CM2)))))**(1/(1+mrho(CM2)));

Equilibrium for one imported commodity

QM(CM1) = QMR('DT',CM1) or QMR('FT',CM1);

Price for one imported commodity

PM(CM1) = PMR('DT',CM1) or PMR('FT',CM1);

Import output value

PM(CM2)*QM(CM2) = SUM(T,PMR(T,CM2)*QMR(T,CM2));

Armington export composite equation

QE(CE2) = ae(CE2)* (edel(CE2)*QER(CE2,'FT')**(erho(CE2))

+(1-edel(CE2))*QER(CE2,'DT')**(erho(CE2))) **(1/erho(CE2));

ROW-RUS export ratio

QER(CE2,'DT')/QER(CE2,'FT') =

((PER(CE2,'DT')/PER(CE2,'FT'))*(edel(CE2)/((1-edel(CE2)))))**(1/(erho(CE2)-1));

Export output value

PE(CE2)*QE(CE2) = SUM(T,PER(CE2,T)*QER(CE2,T));

Quantity for one exported commodity

QE(CE1) = QER(CE1,'DT') or QER(CE1,'FT');

Price for one exported commodity

PE(CE1) = PER(CE1,'DT') or PER(CE1,'FT');

Absorption equation

PQ(C)*QQ(C) = PM(C)*QM(C) + PD(C)*QD(C);

Domestic Output Value

PX(C)*QX(C) = PD(C)*QD(C) + PE(C)*QE(C);

Activity price equation

PA(A) =SUM(C, PX(C)*theta(A,C));

Value added price

PVA(A) = PA(A)*(1 - tb(A)) - SUM(C, PQ(C)*ica(C,A));

Leontief-CES Production Functions

QA(A) =(ad(A)/(1 - tb(A) - SUM(C, ica(C,A))))

* (SUM(FF, del(FF,A)*QF(FF,A)**(-rho(A))))**(-1/rho(A));

Factor demand equation

WFDIST(FF,A)*WF(FF) =PVA(A) * (ad(A)/(1-tb(A)-SUM(C, ica(C,A))))

* (SUM(FFF, del(FFF,A)*QF(FFF,A)**(-rho(A))))**((-1/rho(A))-1)

* del(FF,A)*QF(FF,A)**(-rho(A)-1);

Intermediate input demand equation

QINT(C,A) = ica(C,A)*QA(A);

Output function

QX(C) = SUM(A,theta(A,C)*QA(A)) + SUM(I,IMAKEQ(I,C));

Armington commodity composite supply equation

QQ(CM) = aq(CM)*(adel(CM)*QM(CM)**(-arho(CM))

+(1-adel(CM))*QD(CM)**(-arho(CM))) **(-1/arho(CM));

Import-Domestic demand ratio

QM(CM)/QD(CM) = ((adel(CM)/(1-adel(CM)))*(PD(CM)/PM(CM)))**(1/(1+arho(CM)));

Composite supply for nonimported commodities

QQ(CNM) = QD(CNM);

Output transformation CET equation

QX(CE) = as(CE)* (sdel(CE)*QE(CE)**(srho(CE))+(1-sdel(CE))*QD(CE)**(srho(CE)))
**(1/srho(CE));

Export-domestic supply ratio

QE(CE)/QD(CE) = (PE(CE)/PD(CE)*(1-sdel(CE))/sdel(CE))**(1/(srho(CE)-1));

Output transformation for nonexported commodities

QX(CNE) = QD(CNE);

Factor income

YF(I,FF) = shry(I,FF)*(SUM(A,WFDIST(FF,A)*QF(FF,A)*WF(FF))-SUM(T,SAM(T,FF)));

Household income

YH(H)= SUM(FF,YF(H,FF)) + SUM(C,PX(C)*IMAKEQ(H,C)) + SUM(G,SAM(H,G))+ QIINV(H) + SUM(HH,trh(H,HH)*(1SUM(G,ty(G,HH)))*YH(HH)) + SUM(T,SAM(H,T));

Net household income

NYH(H) = YH(H) - SUM(HH,trh(HH,H)*(1-SUM(G,ty(G,H)))*YH(H))

- SADJ*mps(H)*(1-SUM(G,ty(G,H)))*YH(H) - SUM(G,ty(G,H))*YH(H)

- SUM(T,SAM(T,H));

Household consumption demand

QH(C,H) = lambda(C,H) + (beta(C,H)*(NYH(H)- SUM(CC,lambda(CC,H)*(PQ(CC)))) /PQ(C);

Investment demand

QINV(C) = IADJ*IADJSG1(C)*QINV0(C);

Institutional investment demand

QIINV(H) = IIADJ*QIINVO(H);

Federal government revenue

YFG = SUM((H,FG),ty(FG,H)*YH(H)) + SUM((T,FG),SAM(FG,T))

+ SUM((C,FG),PX(C)*IMAKEQ(FG,C)) + SUM(FG,QIINV(FG))

+ SUM((FG,FGG),SAM(FG,FGG)) + SUM((FG,FF),YF(FG,FF)) + SUM(FG,INDT(FG))

Federal government expenditures

EFG = SUM((FG,I),SAM(I,FG)) + SUM((FG,T),SAM(T,FG)) + SUM((FG,C),PQ(C)*qg(C,FG)) - SUM(FG,SAM('INV',FG));

State government revenue

YSG = SUM((H,SG),ty(SG,H)*YH(H)) + SUM((T,SG),SAM(SG,T)) + SUM((SG,FG),SAM(SG,FG))

+ SUM((C,SG),PX(C)*IMAKEQ(SG,C)) + SUM(SG,QIINV(SG))

+ SUM((SG,SGG),SAM(SG,SGG)) + SUM((SG,FF),YF(SG,FF)) + SUM(SG,INDT(SG))

+ SUM(C,(PM(C)*QM(C) + PD(C)*QD(C))) + SUM((H,C),PQ(C)*QH(C,H));

State government expenditures

ESG = SUM((SG,I),SAM(I,SG)) + SUM((SG,T),SAM(T,SG)) + SGADJ*SUM((SG,C),PQ(C)*qg(C,SG)) - sgovbal;

State government budget balanced

YSG = ESG + sgovbal;

Factor market equation

SUM(A,QF(FF,A)) = QFS(FF);

Composite commodity market equation

QQ(C) = SUM(A,QINT(C,A)) + SUM(H,QH(C,H)) + SUM(FG,qg(C,FG)) + SGADJ*SUM(SG,qg(C,SG)) + QINV(C);

ROW current account balance

SUM(CE,PER(CE,'FT')*QER(CE,'FT')) + SUM(H,SAM(H,'FT')) + SUM(G,SAM(G,'FT')) + XR('FT')*FSAVX=

SUM(CM,PMR('FT',CM)*QMR('FT',CM)) + SUM(FF,SAM('FT',FF)) + SUM(HG,SAM('FT',HG)) + XR('FT')*FSAVM;

RUS current account balance

SUM(CE,PER(CE,'DT')*QER(CE,'DT')) + SUM(H,SAM(H,'DT')) + SUM(G,SAM(G,'DT')) + XR('DT')*DSAVX =

SUM(CM,PMR('DT',CM)*QMR('DT',CM)) + SUM(FF,SAM('DT',FF)) + SUM(HG,SAM('DT',HG)) + XR('DT')*DSAVM;

Savings investment balance

SUM(C,PX(C)*IMAKEQ('INV',C)) + SADJ*SUM(H,mps(H)*(1-SUM(G,ty(G,H)))*YH(H)) + (YFG - EFG) + sgovbal + XR('FT')*FSAVX

+ XR('DT')*DSAVX + SUM(FF,YF('INV',FF))

= SUM(C,PQ(C)*QINV(C)) + SUM(HG,QIINV(HG))

+ XR('DT')*DSAVM + XR('FT')*FSAVM + WALRAS;

Price normalization equation

SUM(C, PQ(C)*cwts(C)) = CPI;

Indirect taxes calculation

INDT(G) = tbshr(G)*SUM(A,tb(A)*PA(A)*QA(A));

Factor supply equation

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QFS(FF) = SHIFTFF(FF)*WF(FF)**efac
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