IMPACT OF SCIENCE AND ENGINEERING GRADUATES ON KEY ECONOMIC INDICATORS

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by

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THESIS

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“Second only to a weapon of mass destruction detonating in an American city, we can think of nothing more dangerous than a failure to manage properly science, technology and education for the common good. . . ” – United States Commission on National Security for the 21st Century, 2001

1. Introduction

A bipartisan group of Senators and Members of Congress asked the National Academies to identify steps necessary for the United States to “successfully compete, prosper, and be secure in the global community of the 21st century.” Among the many results of the study, the committee indicates that firms that perceive a domestic shortage of scientists and engineers (S&E) simply move work outside of the USA. They also state that here is an apparent comparative underrepresentation of US citizens in S&E (16% of undergraduates in the US contrasted against 47% in China, 38% in South Korea and 27% in France), and further that math, science and engineering is the educational area in which America is “failing most convincingly” (Gathering Storm Committe of the National Academy of Sciences, 2010).

Multiple works show the benefits of technological progress, engineering development and similar scientific evolution, including how it extends to many groups in society beyond just the end user and scientist or engineer behind the effort[1]. Of the American workforce, scientists and engineers make up a slim four percent of the total though disproportionately produce jobs for the remaining 96 percent (National Science Board, 2010). The contribution of technology and knowledge in the economy has been examined from Solow, 1957, to Barro and Sala-i-Martin, 2004. Similarly, the role of engineers contributing to localized processes of entrepreneurship (Saxenian, 2006), economic growth (Barro & Sala-i-Martin, 2004) and support of ancillary industries have been analyzed. When it comes to education, Barro and Sala-i-Martin found overall quality of education is more important than the years of schooling with regard to greater economic outcomes. Through both private and public benefits, education has been shown to be a

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[1] See Bivens, J. (2003). “Updated Employment Multipliers for the U.S. Economy”, Economic Policy Institute; Wolff, E. (2000) “Human capital investment and economic growth: exploring the cross-country evidence”, Structural Change and Economic Dynamics; Barro, R., Sala-i-Martin, X. (2003) *Economic Growth*. MIT Press, 2nd Ed. as examples.

stimulant of economic growth that ultimately trickles into per capita income (Baldwin & Borrelli, 2008). While economic studies exist on enrollment rates and years of education relative to economic outcomes, this study seeks to show two variants on that theme; the first variant is discipline specific analysis on scientists and engineers (S&E). The second variant is to use graduation rates rather than enrollment and to evaluate the lagged impact from date of graduation to economic impact as it may be years later.

If those inferences show positive impacts of S&E and are coupled with the current state of education and the number of S&E graduates in the United States, e.g. considering in the period of writing the National Academies Gathering Storm Report, the US fell from first to 16th in tertiary graduation rate (Organization for Economic Cooperation and Development, 2009), then a large concern seems warranted. For multiple years, Manpower Inc.'s Talent Shortage Survey found that U.S. employers stated engineering positions as being the most difficult jobs to fill, even in light of 9% unemployment rates in the nation at the time of surveying. This seems to confirm inferences on either quality of educational systems feeding students into S&E and universities, or the number of S&E graduates from Universities, or both (Weiss, 2009).

It is worth mentioning that the concern over S&E is not a recent development. Current alarmists tend to focus on China and India, which is due to both their growth in S&E output and economic output. Previously, there has been similar concern over the Soviets in decades past. In 1958, the US Congress passed legislation to promote math and science education that was due in part to concerns with international competitiveness and Time magazine notes that advocates “have been pushing for more ever since” (Rotherham, 2011). There are then groups that attribute a portion of the trend in offshoring to the shortage of S&E. However, not all parties have bought into the shortage issue as it pertains to higher education in the US. A study at Duke University concludes that the numbers of S&E graduates reported by China and India are inflated or incomparable to those of the US and that the offshoring trend is due more to sheer cost savings than shortage of skilled labor (Wadhwa, Gereffi, Rissing, & Ong, 2005). Other studies find that the US produces an adequate supply of engineers but that these graduates take finance and consulting jobs in lieu of entering the more traditional research and development (R&D) or engineering workforce (Lowel, Salzman, Bernstein, & Henderson, 2009). It is not the intent of this work to put that debate to rest but rather to quantify the relation between S&E graduates and various economic and technological outcomes. The outcome may be used in combination with market analysis to generate more effective education policies and strategic positioning of the nation. Aside from being economically interesting, it may help to provide a gauge on the severity of the debate and the extent of the impact of S&E graduation rate in economic terms.

2. Contributing Works

As mentioned, the National Academies, the New York Times and a litany of media outlets have publicized the growing gap between the number of engineering graduates in the United States versus rising competitors like China and India[2]. Nearly a third of all U.S. manufacturing companies report suffering from skills shortages and 40% report foreseeing that problem worsen (Deloitte, Oracle, and the Manufacturing Institute, 2009). Of the various employed areas of these responding corporations (HR, IT, sales, marketing, unskilled laborers, etc), the largest shortage of needed employees that was reported were engineers and scientists (36% reporting a shortage). There has been an equal, if not larger, amount of speculation on the extent of the problem and the nature of impact within our changing nation in the face of this shortage. It should also be mentioned that there is some dissent on the magnitude of the shortage and in the ability of public education in the US to train and development the workforce (see Lowell & Salzman, 2007) though economic studies have shown that the globalization of the scientific and engineering workforce is threatening the US economy (Freedman, 2007) and many factors are at work creating a decline in engineers despite relatively high pay and low unemployment (Sturtevant, 2008).

Outside of this debate, there are those that have sought to quantify the relation between economic growth and education, technology and the workforce, including S&E. The conventional method for such macroeconomic impact estimates center on regression analysis to determine the rate of growth per capita (be it income or output) contrasted against an initial level of education (typically total or average years of schooling). Common controls within such works are initial levels of income and influences on steady-state income levels, e.g. openness to trade, quality of the institution or education, and geographic factors (Bloom, Canning, & Chan, 2006). The nature of the engineering job market has been analyzed (Ryoo & Rosen, 2004), the impact of tighter visa measures and international participation in engineering and science (Wang, 2004),

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[2] Revisited: Rising Above the Gathering Storm (2010), NAP, Shortage Of Engineers Plagues Oil Industry (2008), New York Times, US Faces Science Shortage (2004), The Scientist, 5(1), as examples

as well as the contribution of technology and knowledge in the economy (Solow, 1957). The latter is similar to the work here but that work is based on a production function with labor markets and the S&E workforce at the time rather than a tie to S&E graduate rates at the time or in years past. Similarly, Barro and Sala-i-Martin (2004) provide a progression of models that examine the impact of technological shifts on economic growth, as well as the impact of changes in education. The later includes a breakup of male to female education, as well as primary, secondary and tertiary education. Through a cross-sectional study, the level of male educational status, particularly secondary and tertiary education, has a significant and positive growth effect, while female schooling was insignificant. They also reveal a statistically significant interactive relation between initial GDP and human capital in the broad sense of health and education. They do not differentiate between S&E graduates in tertiary education to those of other fields but do find, via a proxy of comparable international education outcomes, that the quality of education is largely more important in terms of partial relation to growth than the bulk years of schooling for the countries under their examination (Barro & Sala-i-Martin, 2004, p. 537).

Pancavel (1991) also tackles the rate of education and its partial relation to economic growth. Aggregate measures of schooling (years) and productivity are used as the inputs to a Cobbs-Douglass derived model that estimates a rise in impact from tertiary education from 1.3% in the timeframe 1913 to 1950 to 14.6% in the timeframe of 1973 to 1984 (Pencavel, 1993, p. 10). Bassanini ve Scarpetta (2001) also used a panel data set with average number of years of education as a proxy in the human capital element. Within these causal relations, co-integration and Granger-causality tests were used in the link between higher education and economic development to identify direction of causality. The work of De Meulemeester and Rochat (1995) show a significant causality between the number of higher education students per capita as they relate to economic development, which was then inferred as a significant causality between higher education and growth (De Meulemeester & Rochat, 1995). These analyses are categorically different than the work herein as they do not distinguish amongst the fields or disciplines of the graduates.

When it comes to differentiation amongst fields, Wolff (2000) does seek to differentiate S&E from other fields by performing an analysis with the number of scientists and engineers engaged in R&D (per 10,000 of the population) to gross national product (GNP) with the inclusion of education as a variable in the human capital element. Among his many results, he shows that a 1% increase in the number of S&E in the R&D workforce relate to a 6.4% increase in growth (1% significance level), though finds that the education variable (university enrollment) has a negative (statistically insignificant) coefficient (Wolff, 2000). However, this work doesn't contrast the S&E graduates against growth or similar output measures. As has been done in other works, here Wolff breaks education into primary, secondary and tertiary enrollments. The work of Lin (2003) does breakdown educational impacts per discipline and further contrasts those disciplines and rates with economic growth. In this case, the work is focused solely on Taiwan over the period of 1965 to 2000, where results did reveal that higher education overall provided a positive and significant effect. This is similar to what has been found in previous models, though in this case specific to Taiwan's economic development. Lin also states that "engineering and the natural sciences majors played the most prominent role" in the economic growth as derived from his estimated relations (Lin, 2004).

3. Model Derivation, Interpretation and Data

3.1 Education Data and Trends

Before proceeding through the model results and data, it is of interest to look at the education statuses of the US and other countries. The figure presented below (Fig. 1) is in bulk numbers and reflects the large increase in the number of Chinese graduates in overall numbers, as well as a similar trend in the Chinese engineering and S&E graduates. The greatest contrast between the US and China can be seen in the rise in slope. It can also be seen that the overall slope pattern for China tends to be mimicked by that of its engineering and S&E graduates. The overall growth of graduates in the US was relatively consistent across the years though engineering was flat. The upward trend in S&E for the US is then largely due to science graduates. The data is drawn from a number of sources[3] and largely compiled by NSF and OECD.

To better visualize the greatest contrast between graduate trends, the engineering graduates are isolated and plotted in figure 2. What is notable is that the Chinese engineering trend dwarfs that of every country. For science, the slope is greater but sheer numbers are not. Perhaps a more interesting look is per capita, as shown in figure 3 and 4. In this case, the graduates are adjusted per 10,000 persons per country. In this case, the general trend between numbers of all graduates is not greatly different, though the trend in engineering is markedly different. The per capita number of science graduates in the US remains dominant in comparison to China but not so for engineering. When it comes to per capita graduates of the countries used in the limited panel study, Taiwan dominates overall graduates and per capita science and

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[3] SOURCES: China—National Bureau of Statistics of China, *China Statistical Yearbook,* annual series (Beijing) (various years); Japan—Government of Japan, Ministry of Education, Culture, Sports, Science and Technology, Monbusho Survey of Education (annual series; various years); Taiwan—Ministry of Education, Educational Statistics of the Republic of China (annual series; various years); United Kingdom—Higher Education Statistics Agency, special tabulations (various years); United States—National Center for Education Statistics, Integrated Postsecondary Education Data System, Completions Survey, and National Science Foundation, Division of Science Resources Statistics, Integrated Science and Engineering Resources Data System (WebCASPAR), http://webcaspar.nsf.gov; and others—Organisation for Economic Co-operation and Development, OECD.Stat Extracts, http://stats.oecd.org/Index.aspx.

engineering graduates. The Taiwanese growth per capita is also dominant. From a study of the numbers, if debate and concern is warranted for the USA, it seems best placed on trends and stagnation in engineering in comparison to the Asian competition.

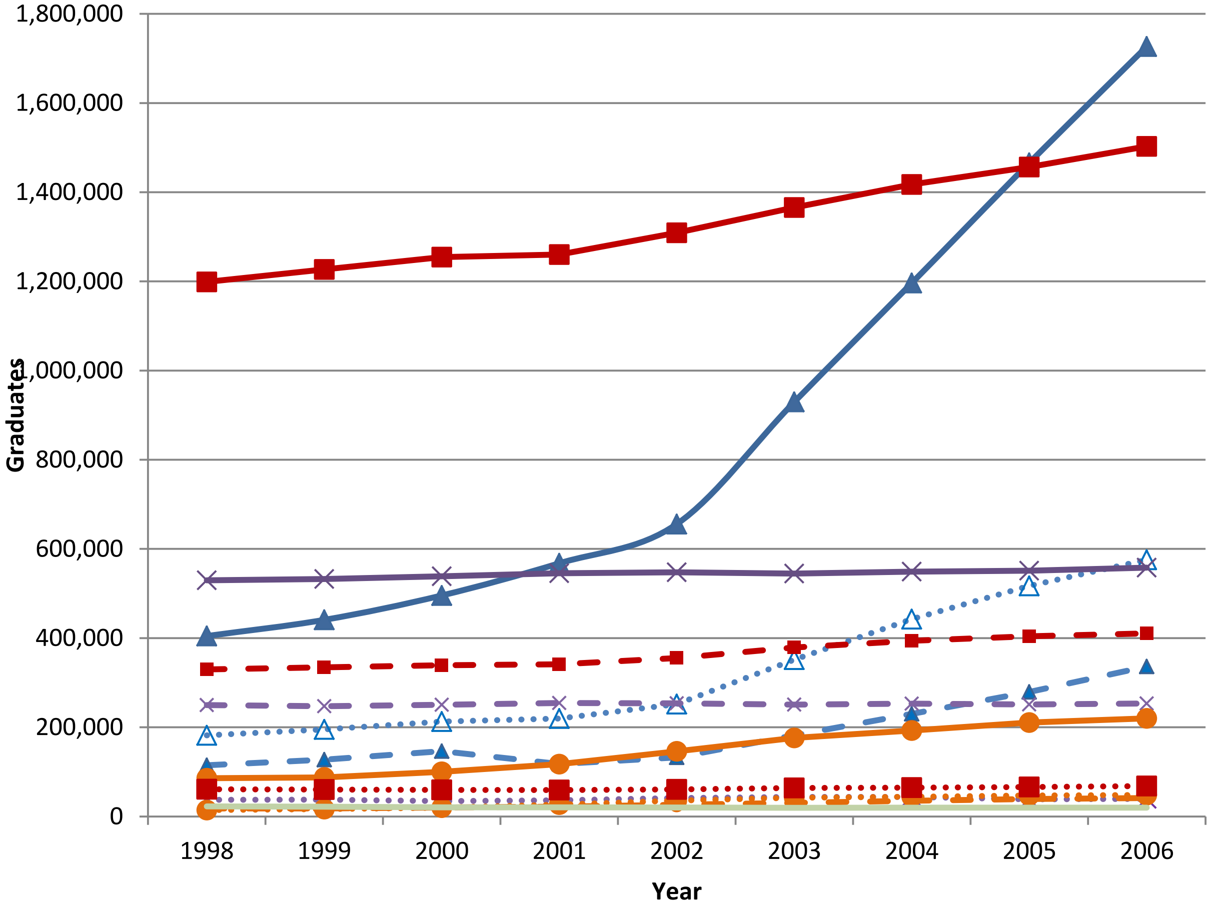

Figure 1: Plot of Graduates across Disciplines and Countries

Where each line is as follows:

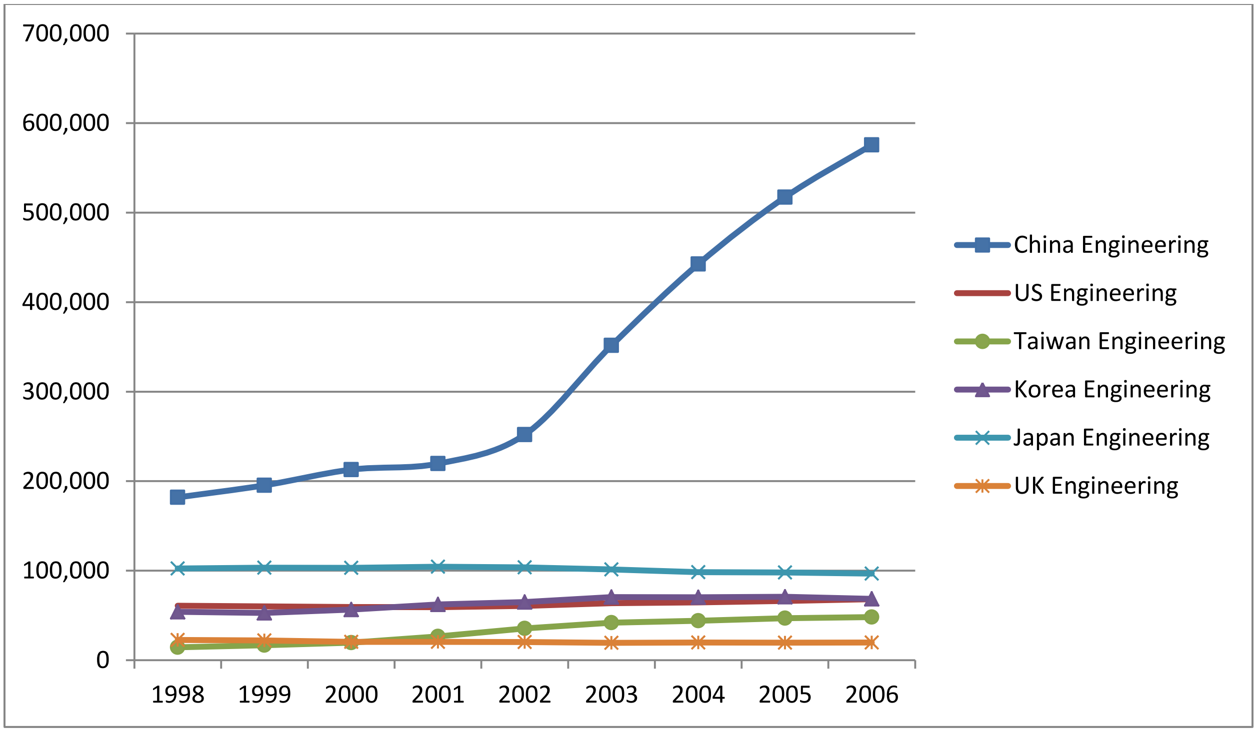

Figure 2: Engineering Graduates per Country

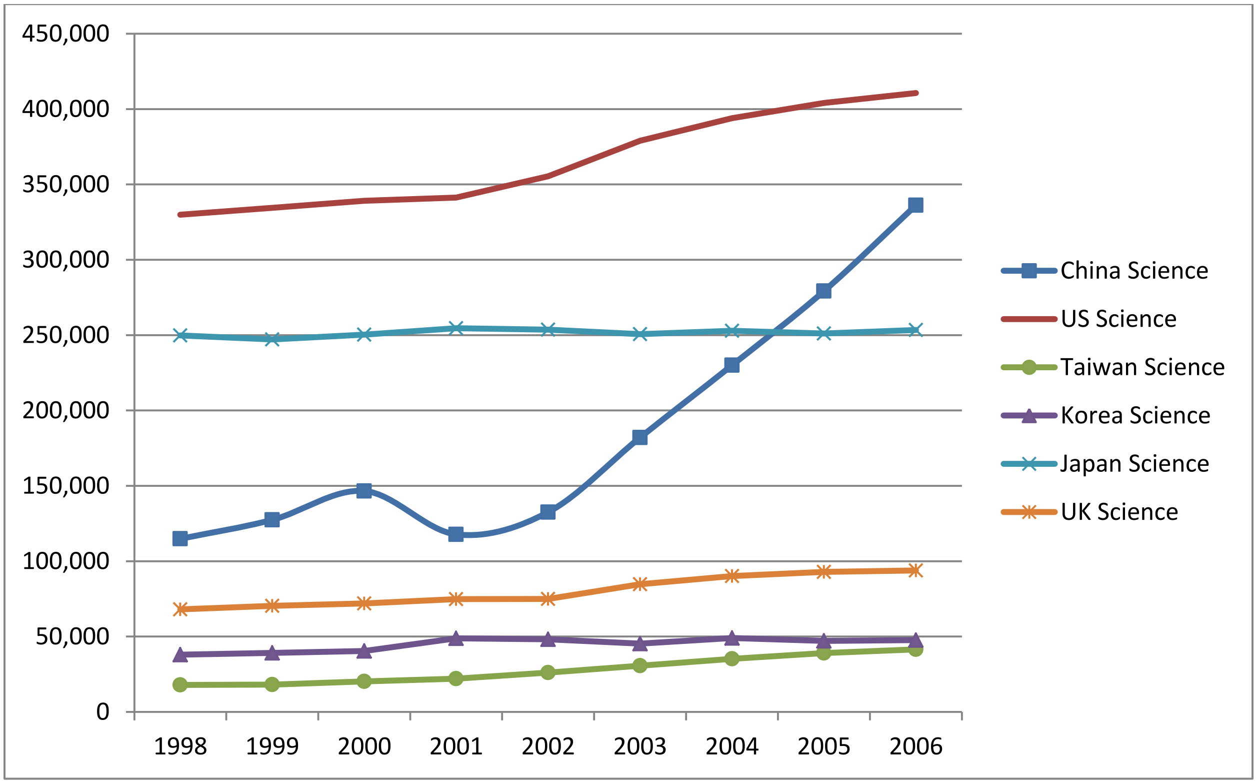

Figure 3: Science Graduates across Countries

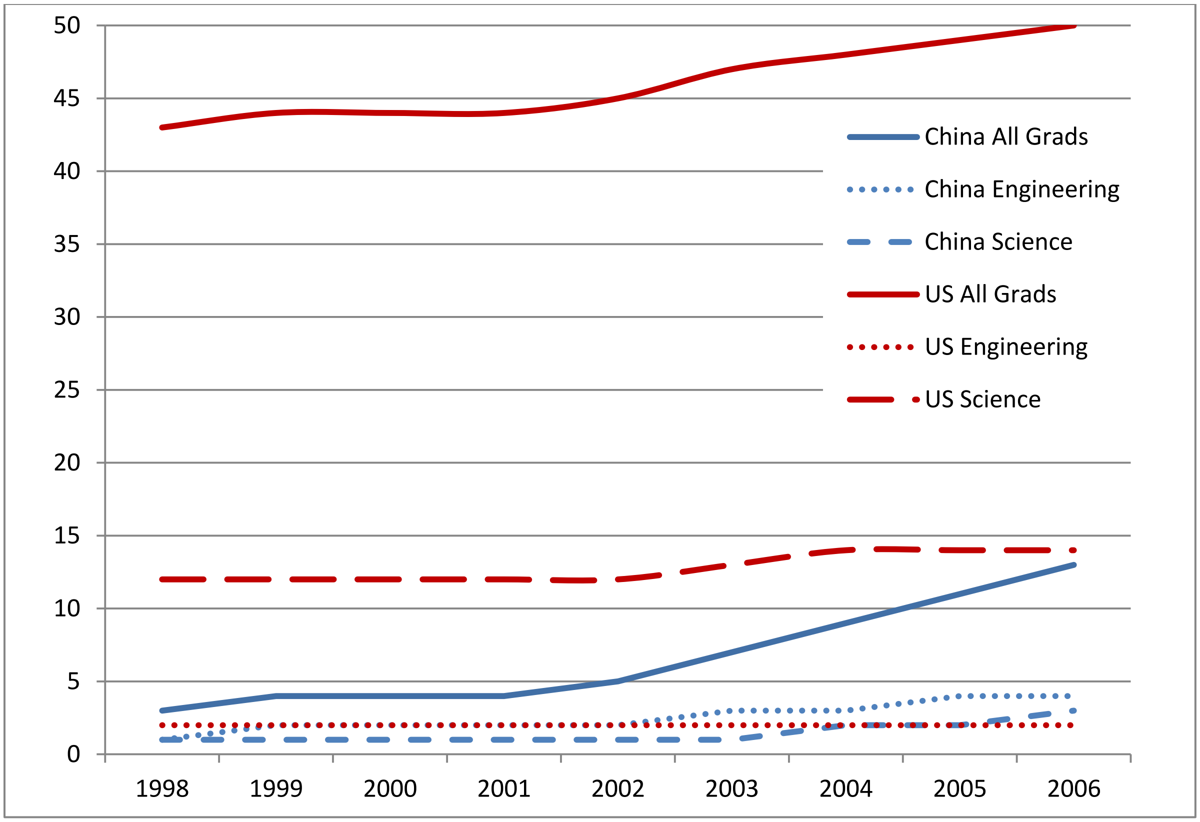

Figure 4: China and USA Graduates Adjusted Per 10,000 Persons

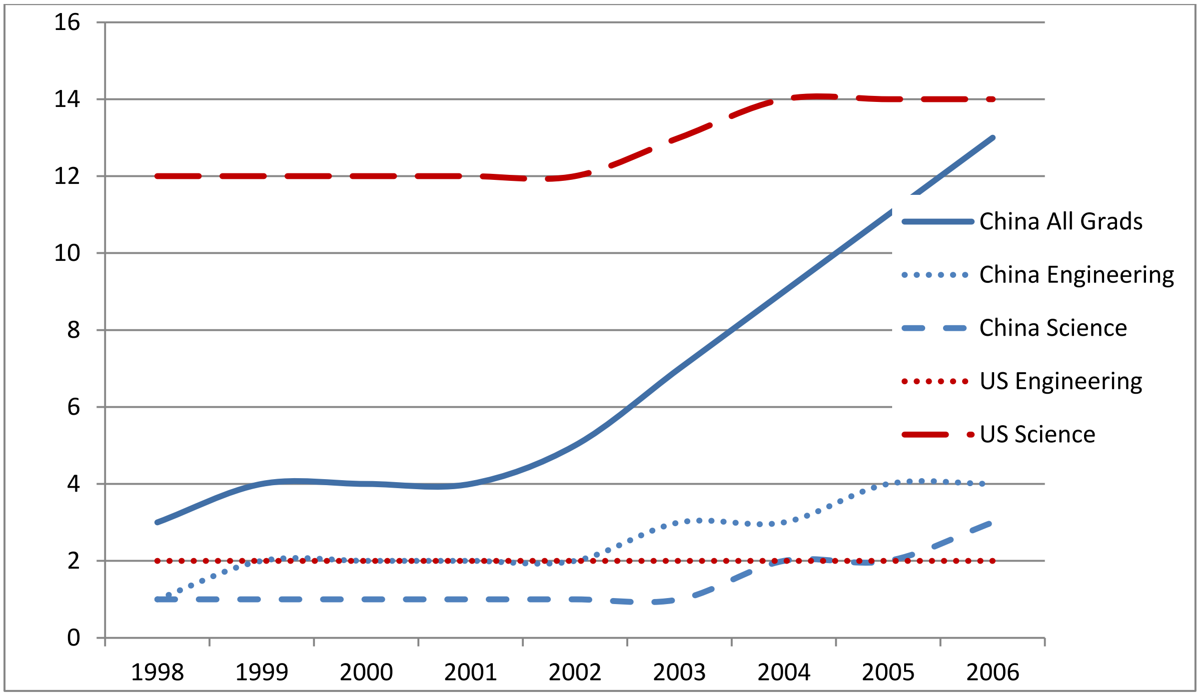

Figure 5: China and USA Graduates per 10,000 Persons (US all grads removed for scaling)

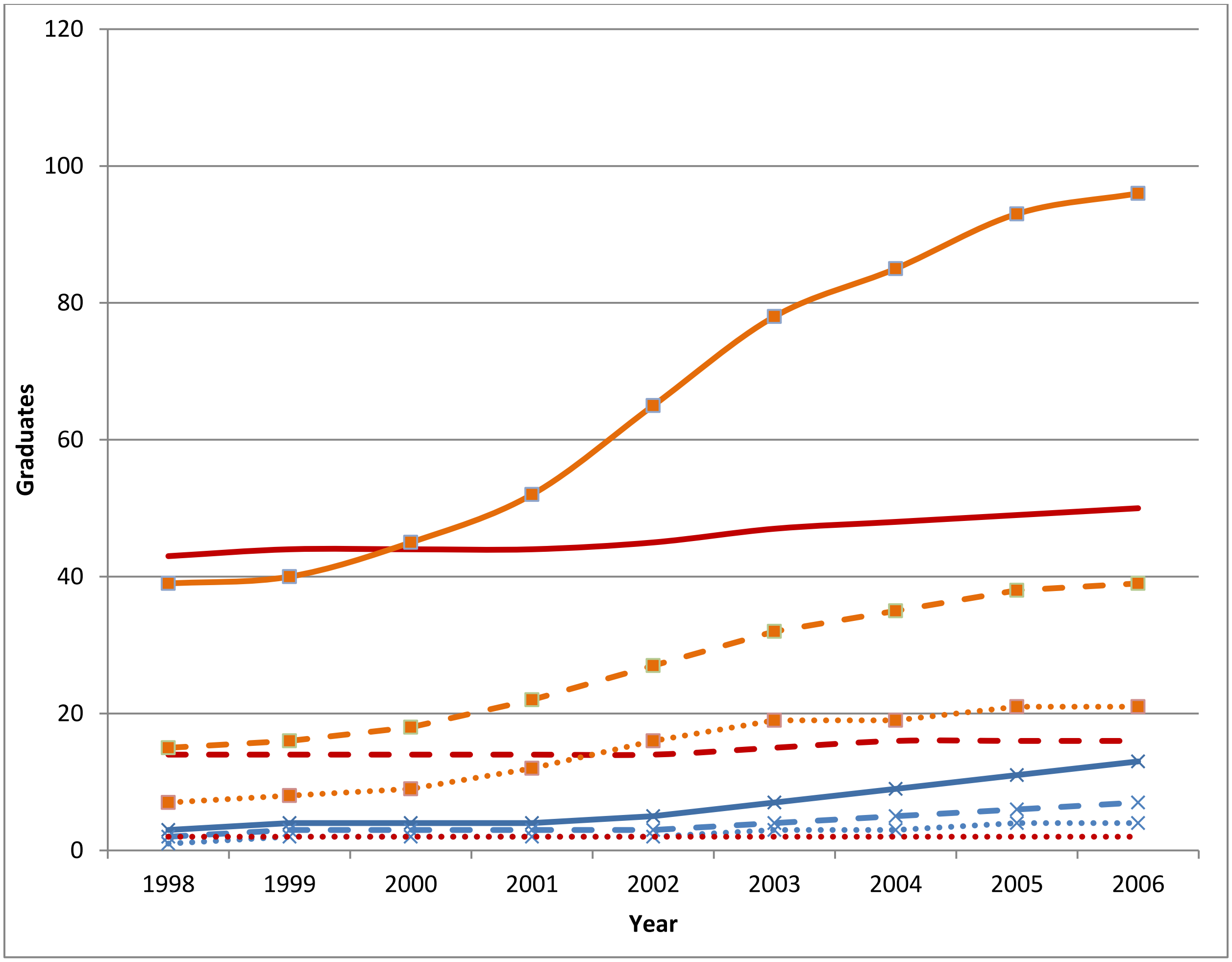

Figure 6: Taiwan, China and the USA Graduates per 10,000 Persons

Where each line is as follows:

4. Model Construct

The approach used in this study is (a) to incorporate a model that allows for the influences of physical, labor and human capital to be assessed on output, (b) to incrementally introduce an increasing number of variables within those categories and (c) to allow for per capita and total value analysis. A common model for such an economic aim is the Cobb-Douglas production model, $Y_t = AK_t^{\alpha}L_t^{\beta}$, which relates output, Y_t, to physical capital, K_t, and labor, L_t, per time period, *t*. In the case of this study, the labor influence is expanded to include human capital, H_t, i.e. $Y_t = AK_t^{\alpha}L_t^{\beta}H_t^{\gamma}$. The α, β, and γ parameters are then the respective elasticities between output and physical, labor and human capital, respectively, as will be shown. For this study, output, Y_t, will be GDP (whether per capita, constant 2000 USD or current international) or National Income (with the same variants as GDP). The thesis centers on the human capital aspect, and in this case specifically it is S&E graduates. The human capital function as it relates to education can be placed in the form shown below by taking the natural log of both sides of the equation above:

$$\ln(Y_t) = \ln\left(AK_t^{\alpha}L_t^{\beta}H_t^{\gamma}\right) = \ln(A) + \ln(K_t^{\alpha}) + \ln\left(L_t^{\beta}\right) + \ln(H_t^{\gamma})$$

$$\ln(Y_t) = C + \alpha * ln(K_t) + \beta * ln(L_t) + \gamma * ln(H_t)$$

Equation 1: model basis for analysis

An error term is then included, ε_t, to render the base model:

$$ln(Y_t) = C + \alpha * ln(K_t) + \beta * ln(L_t) + \gamma * ln(H_t) + \varepsilon_t$$

For this case, the γ term is then the elasticity between the output measure (GDP or National Income) and S&E graduates, as can be seen by taking the partial derivative of Y_t with respect to H_t:

$$\frac{dY}{dH} = \gamma AK_t^{\alpha}L_t^{\beta}H_t^{\gamma-1} = \frac{\gamma AK_t^{\alpha}L_t^{\beta}H_t^{\gamma}}{H} = \gamma\frac{Y}{H}$$

and therefore: $$\gamma = \frac{dY}{dH}\frac{H}{Y} \approx \frac{\%\Delta Y_t}{\%\Delta H_t}$$

- **Table 1: List of variables (dependent, DV, or independent, IV) that are integrated into different variants of the models for analysis**

	Variable	Description	Source	Type
Financial	GDP	GDP per capita (constant 2000 US$)	World Bank, 2011	DV, IV
	GDP	PPP Converted GDP Per Capita, G-K method, at current prices (in I$)	Penn World Table Version 7.0	DV, IV
	NI	Adjusted net national income (constant 2000 US$)	World Bank, 2011	DV, IV
	INVRP	Investment Share of PPP Converted GDP Per Capita at current prices [cgdp], (%)	Penn World Table Version 7.0	IV
	INVR	Investment Share of PPP Converted GDP Per Capita at current prices [cgdp], (in I$)	Penn World Table Version 7.0	IV
	POP	Population	Penn World Table Version 7.0	IV
	CAP	Gross capital formation (constant 2000 US$)	World Bank, 2011	IV
	LABOR	Labor force, total	World Bank, 2011	IV
	UNEMP	Unemployment, total (% of total labor force)	World Bank, 2011	IV
	UNEM	Unemployment, total	World Bank, 2011	IV
Educational	HUMNO	200: Humanities and Arts	OECD Statistics	IV
	ENGO1	All Engineering Classifications within OECD	OECD Statistics	IV
	ENGO2	520: Engineering and engineering trades (ISC 52)	OECD Statistics	IV
	S_EO	All Science & Engineering OECD	OECD Statistics	IV
	S_EU	S&E first university degrees	NSF	IV
	All-BSN	First university degrees	NSF	IV
	ENGN	Engineering first degrees	NSF	IV
	SOCSN	Science first degrees	NSF	IV
	OTHN	First degrees other than S&E	NSF	IV
	All-GRU	Total graduates in all programs. Tertiary. Total	UNESCO	IV
	S_EU	Graduates in S&E. Tertiary. Total	UNESCO	IV
	ENG	Graduates in engineering, manufacturing and construction. Tertiary. Total	World Bank, 2011	IV
	SCI	Graduates in science. Tertiary. Total	World Bank, 2011	IV
	BUS	Graduates in social sciences, business and law. Tertiary. Total	World Bank, 2011	IV

The elasticity relation is the basis of the models that are used in the following pages. The initial model is a log-log relation between GDP and S&E graduates, which accounts only for previous GDP level and S&E graduates while holding all else constant. From that base, numerous variants are integrated into the model of Eq.1 above to incorporate labor, capital and population influences. The variables that were weaved into consideration through the progression of the models are included in the table on the following page. The modeling was broken into two categories, type 1 and type 2. Generally, type 1 modeling had fewer independent variables and no growth parameters in those independent variables. Type 2 used more variables and included growth variables as independent variables. Models progressed from the most simple:

$$\ln(GDP_{i,t}) = C + \ln(GDP_{i,t-1}) + \ln(S\&E_{i,t-lag}) + a_i + \varepsilon_t$$

to the more complex, e.g. $\ln(\frac{GDP_t}{GDP_{t-1}}) = C + \ln(GDP_{t-1}) + \ln(\frac{INVR_t}{INVR_{t-1}}) + \ln(\frac{UNEM_t}{UNEM_{t-1}}) + \ln(OTHGR_{t-lag}) + \ln(S\&E_{t-lag})...$ as variables are added into the model. Note that in the case of panel regression, fixed effects were run for each variant. That is to say, the fixed effect estimator is used to compensate for cross section or time independent influences that are potentially correlated with the independent variables. Similarly, all models used White heteroskedastic correction to compensate for any potential differences in variability among the different parameters used. As will be seen, the averaged S&E impact (elasticity) across all countries for type 1 models is 0.04 and type 2 is 0.06, respectively. That is to say, a 1% change in S&E results in a 0.06% change in GDP. Meanwhile, for the USA-only modeling the elasticities were 0.116 and 0.264, respective to type 1 and type 2 models, when averaged across years of lag.

4.1 USA-Only Modeling

The USA was analyzed on its own to begin the study. In this case, regressions progressed through a series of models in order to determine (i) whether a statistically significant economic impact by engineering and science (S&E) graduates exists on GDP and Income, (ii) determine the number of years between maximum impact and graduation (which can be inferred as S&E maturation, time lag in product/service development, etc) and (iii) how the impact, if any, contrasts with international results that are to found later. For each model, a lag from the year of economic impact (t) versus the time of graduation ($t - x$) is run from 0 to 8 years (x), such that the economic impact of S&E graduates 5 years ago would be S&E taken at $t - 5$.

The model variants for Type 1 construct that were used include the following:

T1.i. Base model: $\ln(GDP_t) = C + \ln(GDP_{t-1}) + \ln(S\,\&\,E_{t-lag}) + \varepsilon_t$

(b) base with time trend, i.e. $\ln(GDP_t) = C + \ln(GDP_{t-1}) + \ln(S\,\&\,E_{t-lag}) + \tau + \varepsilon_t$

T1.ii. Mean GDP Growth: $\ln(\frac{GDP_t}{GDP_{t-1}}) = C + \ln(GDP_{t-1}) + \ln(S\,\&\,E_{t-lag}) +,\varepsilon_t$

(b) with time trend added to model above.

T1.iii. Mean GDP Growth with Investment: $\ln(\frac{GDP_t}{GDP_{t-1}}) = C + \ln(GDP_{t-1}) + \ln(S\,\&\,E_{t-lag}) + \ln(INVR_t) + \varepsilon_t$

(b) with time trend added to model above.

T1.iv. Base model (not growth) with investment: $\ln(GDP_t) = \ln(GDP_{t-1}) + \ln(INVR_t) + \ln(S\,\&\,E_{t-lag}) + \varepsilon_t$
and (b) with time trend added to model above.

The variants for Type 2 Model are then:

T2.i. Capital and Labor with S&E and All Graduates:

$$\ln(\frac{GDP_t}{GDP_{t-1}}) = C + \ln(\frac{CAP_t}{CAP_{t-1}}) + \ln(\frac{UNEM_t}{UNEM_{t-1}}) + \ln(GRAD_{t-lag}) + \ln(S\,\&\,E_{t-lag}) + \varepsilon_t$$

(b) add-in past GDP for convergence

$$\ln(\frac{GDP_t}{GDP_{t-1}}) = C + \ln(GDP_{t-1}) + \ln(\frac{CAP_t}{CAP_{t-1}}) + \ln(\frac{UNEM_t}{UNEM_{t-1}}) + \ln(GRAD_{t-lag}) + \ln(S\,\&\,E_{t-lag}) + \varepsilon_t$$

(c) add-in time trend with previous GDP model.

T2.ii. Capital and Labor with S&E and non-S&E Graduates, (b) and time trend.

$$\ln(\frac{GDP_t}{GDP_{t-1}}) = C + \ln(GDP_{t-1}) + \ln(\frac{CAP_t}{CAP_{t-1}}) + \ln(\frac{UNEM_t}{UNEM_{t-1}}) + \ln(OTHGR_{t-lag}) + \ln(S\,\&\,E_{t-lag}) + \tau + \varepsilon_t$$

T2.iii. Exchange capital formation for Investment as Share of GDP, (b) and time trend.

$$\ln(\frac{GDP_t}{GDP_{t-1}}) = C + \ln(GDP_{t-1}) + \ln(\frac{INVR_t}{INVR_{t-1}}) + \ln(\frac{UNEM_t}{UNEM_{t-1}}) + \ln(OTHGR_{t-lag}) + \ln(S\,\&\,E_{t-lag}) + \tau + \varepsilon_t$$

T2.iv. Run the above with GDP in International Current Dollar and 2000 Constant USD

Most model results of the Type 1 construct show a maximum impact occurring around four years from graduation to impact (on GDP or national income). As such, the regression output results for various Type 1 models at year 4 are provided in detail below. Summary tables are provided in the appendix across the range of lags and for various model variants. Greater statistical detail is also provided in the appendix for reference. Similarly within the Type 2 construct, tables are also provided that show the results per year of lag for every other model. The Type 2 Model is a Cobbs-Douglass based derivation, as previously given above, which is then varied to include an increasing number of independent variables. National Income and GDP served as the dependent variables though the trend in impact was largely the same and therefore the GDP variants of the models tend to be presented.

Note that for Model 1 and 2 the change in S&E graduates and the mean rate of growth change of S&E was run within each model variant above. In nearly each case, the mean rate of change rendered insignificant results with coefficients that went against theory in the sign of their values, e.g. an increase in unemployment resulting in an increase in GDP and vice versa for education. With regard to data, variations in reported education statistics exist depending on the source and the definitions by which the source defined graduates and disciplines. In the case of the USA only study, the NSF provided a larger body of data for the US[4] and as such that data was used in the analysis. Data sources for the panel analysis were provided earlier.

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[4] Tabulated by National Science Foundation/Division of Science Resources Statistics (NSF/SRS); data from Department of Education/National Center for Education Statistics: Integrated Postsecondary Education Data System Completions Survey and NSF/SRS: Survey of Earned Doctorates, taken from NSF online database Aug 2011.

4.1.1 USA-Only Results Via Type 1 Modeling

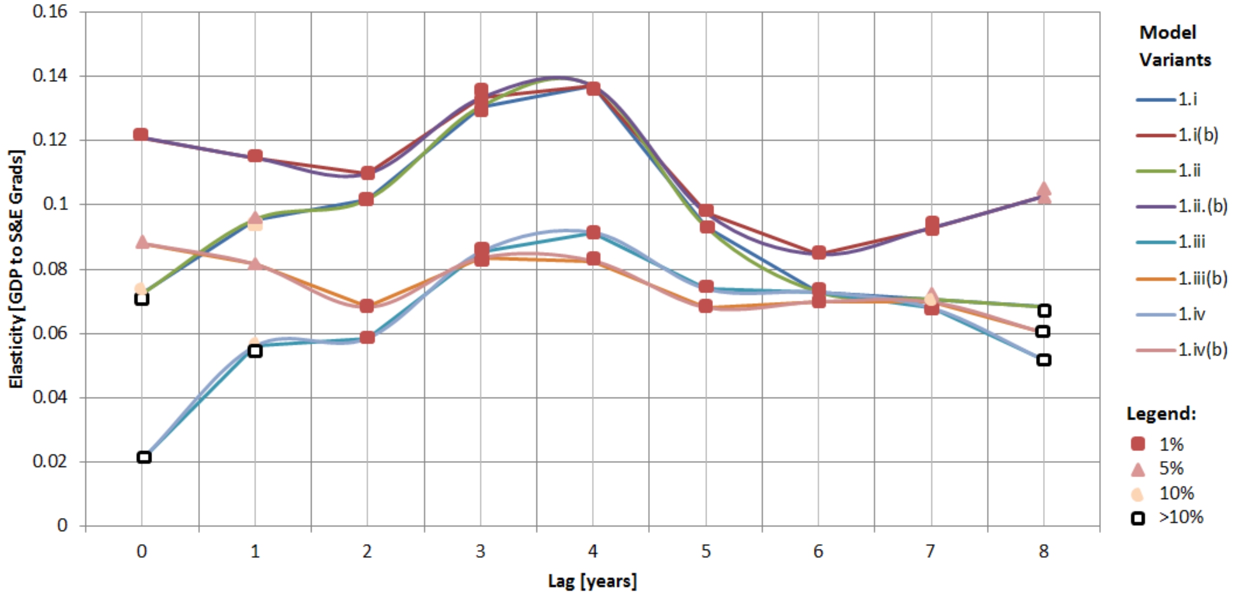


Figure 7: Graph of Elasticity between GDP and S&E Graduates (lagged in years) – Type 1

A discernible trend exists in the variants of the model that indicate a maximum impact occurs around 4 years after a scientist or engineer graduates. Note that the various points along each plot are marked and color coded according to statistical significance. The following table presents the coefficient values and standard errors for a 4 year lag. The F-statistic for all coefficients per variable is also given along with number of observations in the model. Similar results for Model 2, which follows the model 1 section, are also presented.

Table 2: Coefficients and resulting statistics per Model 1 Variants of S&E on GDP or GDP Growth

Model	S&E Coef	SE(S&E)	Model F-stat	Obs
1.i	0.137	0.026	39291.050	37
1.i(b)	0.137	0.027	25434.540	37
1.ii	0.137	0.026	25434.540	37
1.ii(b)	0.137	0.027	17.390	37
1.iii	0.091	0.027	35.815	37
1.iii(b)	0.083	0.026	30.597	37
1.iv	0.091	0.027	41949.600	37
1.iv(b)	0.083	0.026	34586.860	37

Average 0.112 with standard dev. of 0.03

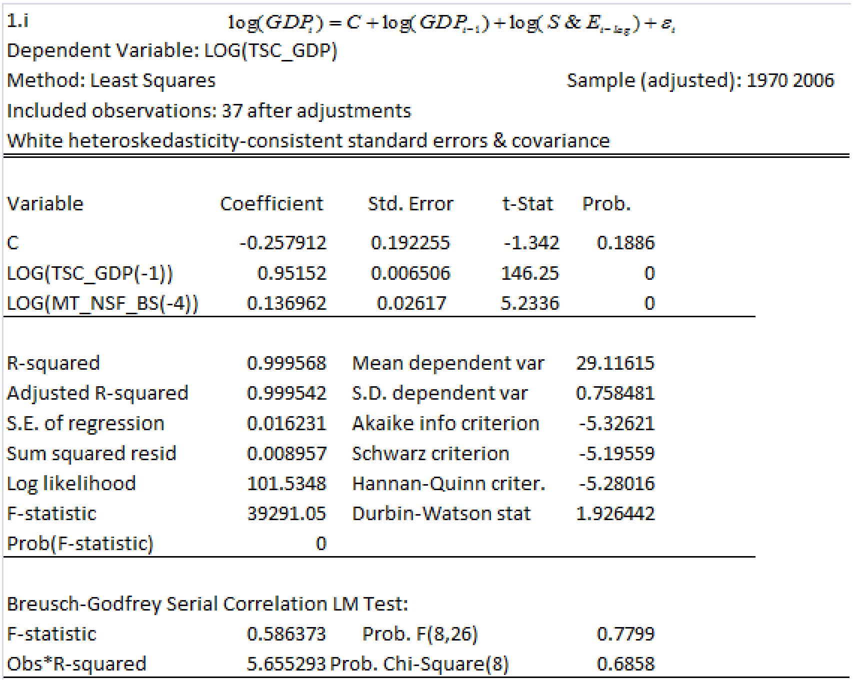
The following tables summarize the results for model *iv,* showing all coefficients and a color coded system indicating statistical significance, if any. As mentioned, the results for every other model variant are provided in the appendix in similar format to the table below.

Table 3: model results for 1.iv across range of lags $\ln(\frac{GDP_t}{GDP_{t-1}}) = C + \ln(GDP_{t-1}) + \ln(S \,\&\, E_{t-lag}) + \ln(INVR_t) + \varepsilon_t$

S&E Lag	GDP	Constant	GDP-1	INVR	S&E
0	Growth	1.02255***	-0.191454***	0.158018***	0.020844
1	Growth	0.736102**	-0.184787***	0.145091***	0.056068*
2	Growth	0.764954***	-0.180763***	0.138688***	0.058582***
3	Growth	0.559663**	-0.174057***	0.126732***	0.085385***
4	Growth	0.582966**	-0.180573***	0.130035***	0.091473***
5	Growth	0.831817***	-0.189153***	0.138223***	0.073946***
6	Growth	0.943762***	-0.201208***	0.147456***	0.072871***
7	Growth	1.062721***	-0.207396***	0.15198***	0.068001***
8	Growth	1.247708***	-0.212458***	0.158125***	0.051761

where *, **, and *** are significant at 10%, 5%, and 1%, respectively.

Table 4: Statistical details of the output of Model 1.i at a 4 year lag of S&E graduates on GDP



1.i $\log(GDP_t) = C + \log(GDP_{t-1}) + \log(S \,\&\, E_{t-lag}) + \varepsilon_t$

Dependent Variable: LOG(TSC_GDP)

Method: Least Squares Sample (adjusted): 1970 2006

Included observations: 37 after adjustments

White heteroskedasticity-consistent standard errors & covariance

Variable	Coefficient	Std. Error	t-Stat	Prob.
C	-0.257912	0.192255	-1.342	0.1886
LOG(TSC_GDP(-1))	0.95152	0.006506	146.25	0
LOG(MT_NSF_BS(-4))	0.136962	0.02617	5.2336	0

R-squared	0.999568	Mean dependent var	29.11615
Adjusted R-squared	0.999542	S.D. dependent var	0.758481
S.E. of regression	0.016231	Akaike info criterion	-5.32621
Sum squared resid	0.008957	Schwarz criterion	-5.19559
Log likelihood	101.5348	Hannan-Quinn criter.	-5.28016
F-statistic	39291.05	Durbin-Watson stat	1.926442
Prob(F-statistic)	0		

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.586373	Prob. F(8,26)	0.7799
Obs*R-squared	5.655293	Prob. Chi-Square(8)	0.6858

4.1.2 USA-Only Results via Type 2 Modeling

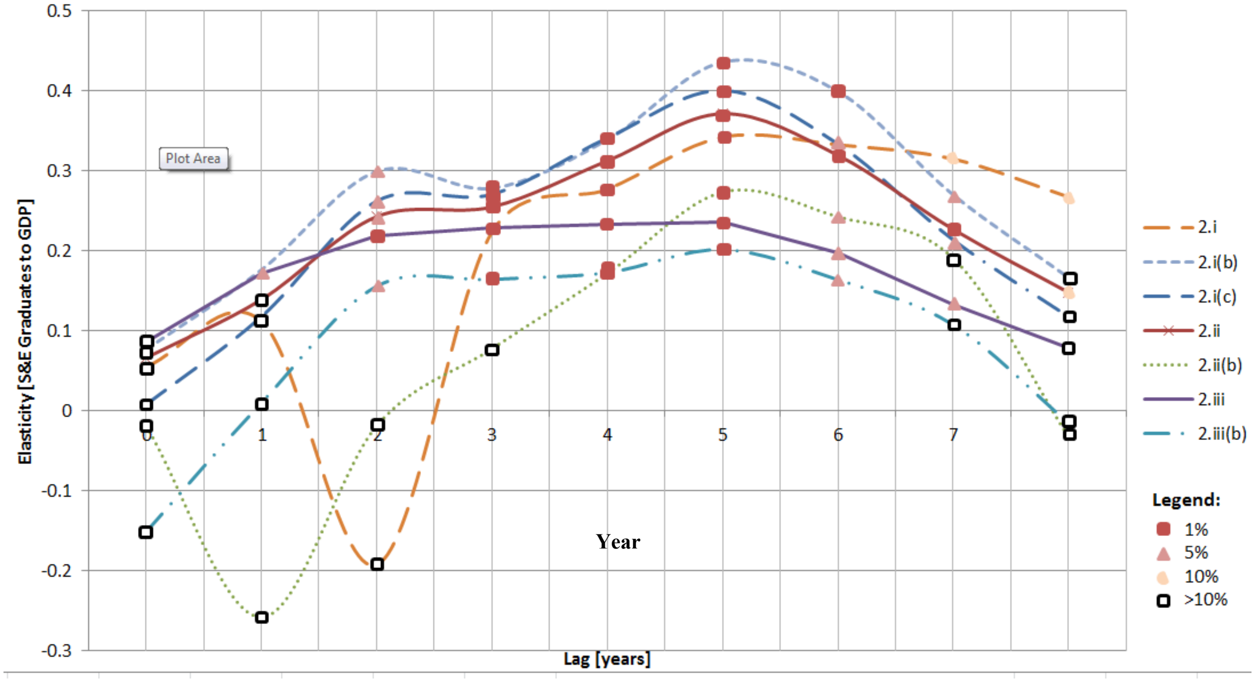


Figure 8: Graph of Elasticity between GDP and S&E Graduates (lagged in years) – Type 2 Model

Table 5: Coefficients and statistics for S&E impact on GDP or GDP growth with a 4 year lag

Model	S&E Coef	SE(S&E)	Model F-stat	Obs
2.i	0.277	0.076	6.358	26
2.i(b)	0.339	0.076	6.862	26
2.i(c)	0.341	0.069	10.474	26
2.ii	0.312	0.074	16.378	26
2.ii(b)	0.171	0.060	10.472	26
2.iii	0.232	0.041	28.210	26
2.iii(b)	0.173	0.047	27.850	26
Average	0.264	with standard dev. of 0.07		

For the model below, results are presented in table 6, as follows. A sample of the Model 2 results is also provided in greater statistical detail. The results for each variant of Model 2 construct at a 4 year lag are provided in Appendix B. However, it should be noted that in the case of Model 2, the maximum return from S&E graduates to Economic Indicators such as GDP,

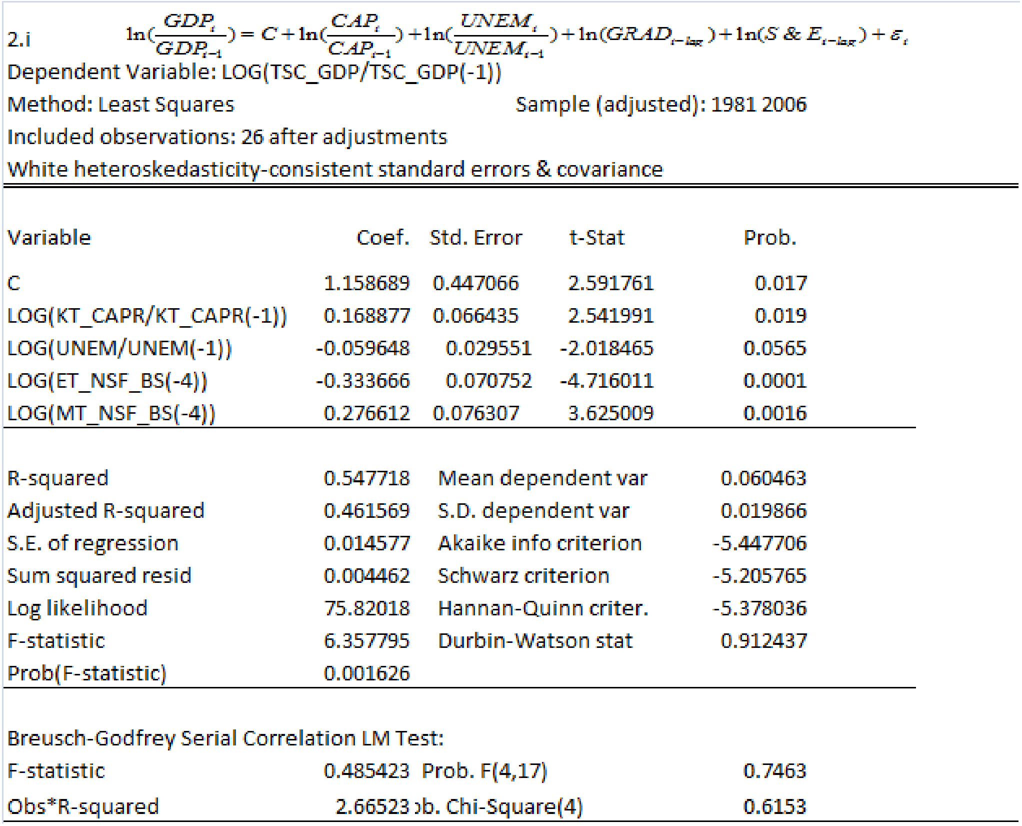
GDP Growth, National Income and National Income growth is at 5 years compared to the 4 found in the Type 1 modeling.

$$\ln\left(\frac{GDP_t}{GDP_{t-1}}\right) = C + \ln(GDP_{t-1}) + \ln\left(\frac{INVR_t}{INVR_{t-1}}\right) + \ln\left(\frac{UNEM_t}{UNEM_{t-1}}\right) + \ln(OTHGR_{t-lag}) + \ln(S\,\&\,E_{t-lag}) + \varepsilon_t$$

Table 6: Summary of Results for Model 2.iii across Range of Lag

S&E Lag	GDP	Constant	GDP-1	INVR	UNEM	OTH-GRAD	S&E
0	Growth	0.29816	-0.035304*	0.213187***	0.012196	-0.022844	0.085656
1	Growth	0.171315	-0.038032**	0.240023***	0.037688	-0.088522	0.171324**
2	Growth	-0.100426	-0.047974***	0.236365***	0.036498	-0.091967*	0.219269***
3	Growth	-0.350093	-0.05482***	0.232556***	0.018904	-0.067248	0.228613***
4	Growth	-0.567232*	-0.059792***	0.203092***	-0.012858	-0.043571	0.232364***
5	Growth	-0.869753**	-0.068038***	0.159542***	-0.044455	-0.005824	0.235587***
6	Growth	-0.800777**	-0.061717***	0.150895***	-0.049601*	0.012363	0.196504***
7	Growth	-0.694174*	-0.054229***	0.147741***	-0.045509*	0.048955	0.132232**
8	Growth	-0.420113	-0.043979***	0.179531***	-0.026904	0.05707	0.078325

Table 7: Statistical details of Model 2.i at a 4 year lag for S&E on GDP growth



2.i $\ln\left(\frac{GDP_t}{GDP_{t-1}}\right) = C + \ln\left(\frac{CAP_t}{CAP_{t-1}}\right) + \ln\left(\frac{UNEM_t}{UNEM_{t-1}}\right) + \ln(GRAD_{t-lag}) + \ln(S\,\&\,E_{t-lag}) + \varepsilon_t$

```
Dependent Variable: LOG(TSC_GDP/TSC_GDP(-1))
Method: Least Squares                          Sample (adjusted): 1981 2006
Included observations: 26 after adjustments
White heteroskedasticity-consistent standard errors & covariance

Variable                      Coef.  Std. Error    t-Stat          Prob.

C                          1.158689  0.447066    2.591761          0.017
LOG(KT_CAPR/KT_CAPR(-1))   0.168877  0.066435    2.541991          0.019
LOG(UNEM/UNEM(-1))        -0.059648   0.029551  -2.018465         0.0565
LOG(ET_NSF_BS(-4))        -0.333666   0.070752  -4.716011         0.0001
LOG(MT_NSF_BS(-4))         0.276612  0.076307    3.625009         0.0016

R-squared                  0.547718   Mean dependent var         0.060463
Adjusted R-squared         0.461569   S.D. dependent var         0.019866
S.E. of regression         0.014577   Akaike info criterion     -5.447706
Sum squared resid          0.004462   Schwarz criterion         -5.205765
Log likelihood             75.82018   Hannan-Quinn criter.      -5.378036
F-statistic                6.357795   Durbin-Watson stat         0.912437
Prob(F-statistic)          0.001626

Breusch-Godfrey Serial Correlation LM Test:
F-statistic                0.485423  Prob. F(4,17)                 0.7463
Obs*R-squared               2.66523 ob. Chi-Square(4)              0.6153
```

4.1.3 USA-Only Summary

The results of S&E impact on the Type 1 variants varied from 0.083 to 0.137. In most cases, an addition of time trending had no effect on S&E coefficient and solely or mostly on the effect of prior year's GDP or national income. The average of 0.112 indicates that a 1% change in S&E results in a 0.112% change in GDP. By contrast, Lin (2004) found a 1% change in S&E for Taiwan results in a 0.19% change in Taiwanese GDP using similar but not identical modeling. The variants of the Type 2 modeling, the Cobb-Douglas derivative with physical and human capital inclusion, resulted in an average elasticity over twice as great as the more simple GDP-to-S&E of Type 1, namely 0.264%. Wolff (2000) found values of 0.031 to 0.071, but using a log(GDP) to unit value S&E relative to 10,000. In this case, the S&E was scientists and engineers engaged in R&D and the reported value is not an elasticity as is the case herein. The relation Wolff found is not directly comparable to the result presented herein, nor is the statistically significant relation of male higher education in a similar log(GDP) to unit value reported to be 0.055 (Barro & Sala-i-Martin, 2004). However, like the Taiwanese study, the relative measures are within ballpark when considering the results found for the USA-only study of this work.

4.2 Multi-Country Panel Analysis

By expanding from the USA only regression analysis, countries and their respective data are added into variants of Type 1 and Type 2 panel models. In this case, the inferences sought are similar to previous, namely (i) statistically significant impact between engineers and scientists (S&E), and (ii) number of years between maximum impact and graduation (as can be inferred as S&E maturation, time lag in product/service development, etc). Like the USA modeling, each panel model is run with a lag from the time of graduation to the year for that period *t* from 0 to 8 years.

Model variants for Type 1 Model:

T1P.i Base model: $\ln(GDP_{i,t}) = C + \ln(GDP_{i,t-1}) + \ln(S\&E_{i,t-lag}) + a_i + \varepsilon_{i,t}$

(b) base with time trend, i.e. $\ln(GDP_{i,t}) = C + \ln(GDP_{i,t-1}) + \ln(S\,\&\,E_{i,t-lag}) + a_i + \tau + \varepsilon_{i,t}$

T1P.ii Investment addition to base: $\ln(GDP_{i,t}) = \ln(GDP_{i,t-1}) + \ln(INVR_{i,t}) + \ln(S\,\&\,E_{i,t-lag}) + a_i +, \varepsilon_t$

(b) with time trend added to model *ii* above.

T1P.iii Mean GDP Growth with Investment: $\ln(\frac{GDP_{i,t}}{GDP_{i,t-1}}) = C + \ln(GDP_{i,t-1}) + \ln(S\,\&\,E_{i,t-lag}) + \ln(INVR_{i,t}) + a_i + \varepsilon_t$

(b) with time trend added to model *iii* above.

T1P.iv Population consideration into growth model:

$$\ln(\frac{GDP_{i,t}}{GDP_{i,t}}) = \ln(GDP_{i,t-1}) + \ln(INVR_{i,t}) + \ln(S\,\&\,E_{i,t-lag}) + \log(pop_{i,t}) + \tau + a_i + \varepsilon_t$$

(b) same model but on the value rather than growth of GDP.

T1P.v Engineering isolated against humanities: $\ln(\frac{GDP_{i,t}}{GDP_{i,t}}) = \ln(GDP_{i,t-1}) + \ln(ENG_{i,t-lag}) + \ln(HUMN_{i,t-lag}) + \tau + a_i + \varepsilon_t$

Two sets of data were run in the panel analysis. The first, consisting of 27 countries, was comprised predominantly of developed countries though did included China and a couple of developing countries at the time periods covered. The second set was done with 237 countries, though for many of those countries the contribution to observations was small due to limited data, in particular education data. Perhaps not unsurprisingly, the results are more diverse and do not hold statistical significance across the range of lagged years as did the USA-only regression. The following graph reflects the contrast in the model results for the 27 country data. The maximum return in this case from S&E graduates appears to be either year 3 or year 7, with more models returning a larger impact in year 7. Models largely returned statistically insignificant results for S&E graduates for years 4, 5 and 8. Model results for the type 2 model are then added to the figure and provide further evidence of maximum return at or near year 7. Note that the time trend variants of the models (notated as *(b)*) followed the general trend of the base model and thus are not shown for clarity in the graph. With the addition of model 2 type variants, as will be shown below, the S&E graduate impact seems to be near the 6.5 mark in years. The value of these elasticities is provided after the figure, as well as a sample of statistical outputs for various models. As with previous, the appendix holds statistical outputs per model variant.

Model 2 variants for Type 2 Model:

T2P.i Capital and Labor with S&E and All Graduates:

$$\ln(\frac{GDP_{i,t}}{GDP_{i,t-1}}) = C + \ln(\frac{CAP_{i,t}}{CAP_{i,t-1}}) + \ln(\frac{UNEM_{i,t}}{UNEM_{i,t-1}}) + \ln(GRAD_{i,t-lag}) + \ln(S\,\&\,E_{i,t-lag}) + a_i + \varepsilon_t$$

(b) add-in time trend,

(c) add-in past GDP for convergence

$$\ln(\frac{GDP_{i,t}}{GDP_{i,t-1}}) = C + \ln(GDP_{i,t-1}) + \ln(\frac{CAP_{i,t}}{CAP_{i,t-1}}) + \ln(\frac{UNEM_{i,t}}{UNEM_{i,t-1}}) + \ln(GRAD_{i,t-lag}) + \ln(S\,\&\,E_{i,t-lag}) + a_i + \varepsilon_t$$

(d) add-in time trend with previous GDP model.

T2P.ii Capital and Labor with S&E and non-S&E Graduates, (b) and time trend.

$$\ln(\frac{GDP_{i,t}}{GDP_{i,t-1}}) = C + \ln(GDP_{i,t-1}) + \ln(\frac{CAP_{i,t}}{CAP_{i,t-1}}) + \ln(\frac{UNEM_{i,t}}{UNEM_{i,t-1}}) + \ln(OTHGR_{i,t-lag}) + \ln(S\,\&\,E_{i,t-lag}) + a_i + \tau + \varepsilon_t$$

T2P.iii Exchange capital formation for Investment as Share of GDP, (b) and time trend.

$$\ln(\frac{GDP_{i,t}}{GDP_{i,t-1}}) = C + \ln(GDP_{i,t-1}) + \ln(\frac{INVR_{i,t}}{INVR_{i,t-1}}) + \ln(\frac{UNEM_{i,t}}{UNEM_{i,t-1}}) + \ln(OTHGR_{i,t-lag}) + \ln(S\,\&\,E_{i,t-lag}) + a_i + \tau + \varepsilon_t$$

4.2.1 Panel Multi-Country Results via Type 1 Modeling

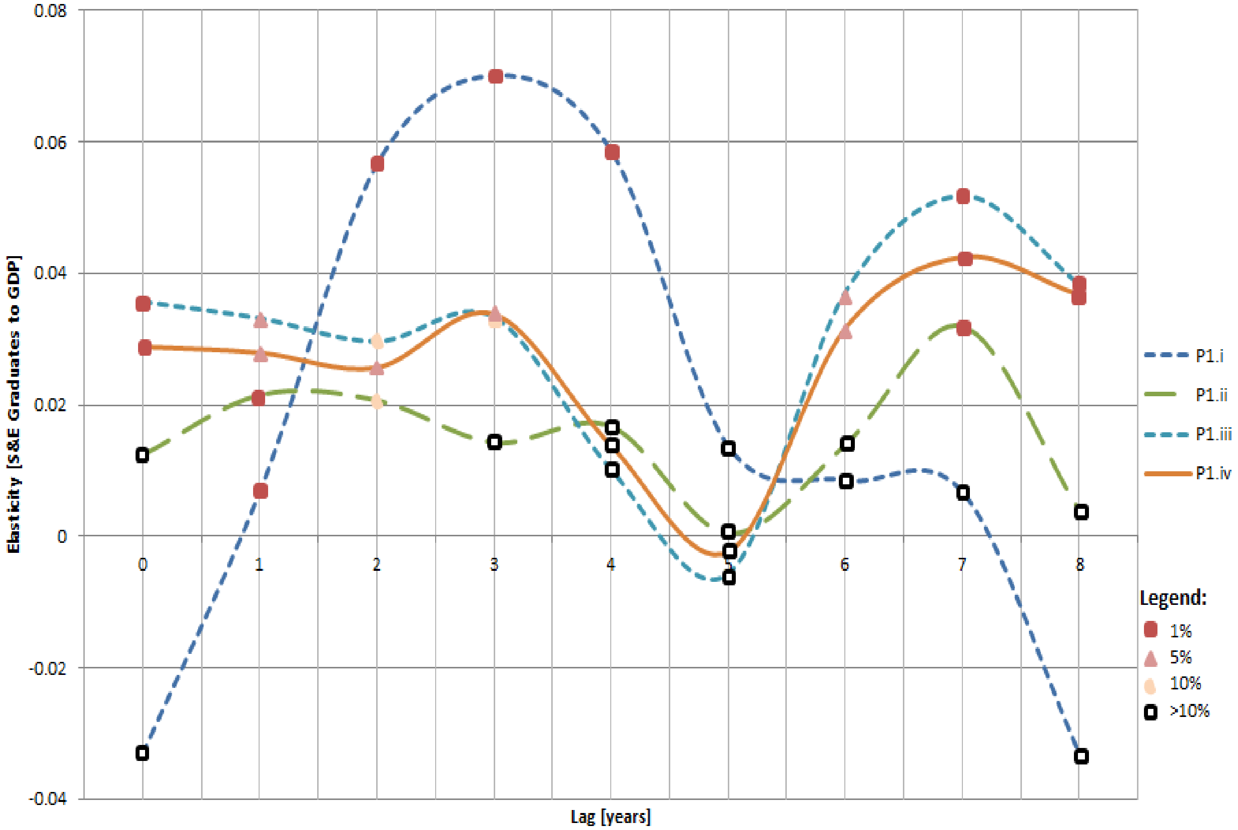


Figure 9: S&E graduates to GDP versus years of lag from graduation for Model 1 and Data Set 1

The table below shows the trend across the range of lags for Panel Model 1.iii.

Table 8: Results of Panel Model 1.iii across the range of lags

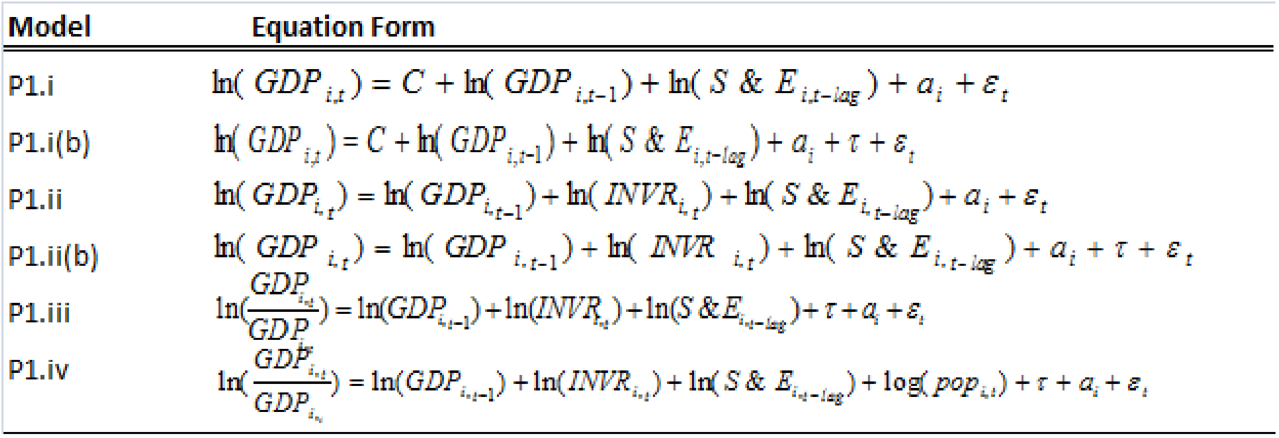
$$\ln(\frac{GDP_{i,t}}{GDP_{i,t}}) = \ln(GDP_{i,t-1}) + \ln(INVR_{i,t}) + \ln(S\&E_{i,t-lag}) + \tau + a_i + \varepsilon_t$$

S&E Lag	GDP	Constant	GDP-1	S&E	T	INVR
0	Growth	-6.316883**	-0.344117***	0.035684***	0.003833***	0.206181***
1	Growth	-7.057466**	-0.369742***	0.033162**	0.004332***	0.209347***
2	Growth	-5.766001*	-0.369228***	0.029615*	0.003677**	0.215457***
3	Growth	-6.770137*	-0.388836***	0.033349*	0.004272**	0.212538***
4	Growth	-11.78556**	-0.42835***	0.010128	0.007051***	0.221523***
5	Growth	-7.29373	-0.391908***	-0.005747	0.004784	0.204057***
6	Growth	-6.893988	-0.455116***	0.037137**	0.004691	0.204298***
7	Growth	-3.191524	-0.518578***	0.051792***	0.003193	0.183242***
8	Growth	3.741245	-0.537174***	0.038293***	-0.0001	0.18466***

Table 9: S&E Coefficient values and statistics for Panel Model 1 results

Model	S&E Coef	SE(S&E)	Model F-stat	Obs	Lag
P1.i	0.070	0.017	682.402	226	3
P1.i(b)	0.064	0.019	816.271	226	3
P1.ii	0.032	0.012	1188.910	120	7
P1.ii(b)	0.024	0.015	1230.750	120	7
P1.iii	0.052	0.018	19.739	87	7
P1.iv	0.022	0.012	16.193	120	7
Average	0.044	SD of Avg	0.021		

Table 10: S&E Model equations for Panel Model 1 results



Model	Equation Form
P1.i	$\ln(GDP_{i,t}) = C + \ln(GDP_{i,t-1}) + \ln(S\&E_{i,t-lag}) + a_i + \varepsilon_t$
P1.i(b)	$\ln(GDP_{i,t}) = C + \ln(GDP_{i,t-1}) + \ln(S\&E_{i,t-lag}) + a_i + \tau + \varepsilon_t$
P1.ii	$\ln(GDP_{i,t}) = \ln(GDP_{i,t-1}) + \ln(INVR_{i,t}) + \ln(S\&E_{i,t-lag}) + a_i + \varepsilon_t$
P1.ii(b)	$\ln(GDP_{i,t}) = \ln(GDP_{i,t-1}) + \ln(INVR_{i,t}) + \ln(S\&E_{i,t-lag}) + a_i + \tau + \varepsilon_t$
P1.iii	$\ln(\frac{GDP_{i,t}}{GDP_{i,t}}) = \ln(GDP_{i,t-1}) + \ln(INVR_{i,t}) + \ln(S\&E_{i,t-lag}) + \tau + a_i + \varepsilon_t$
P1.iv	$\ln(\frac{GDP_{i,t}}{GDP_{i,t}}) = \ln(GDP_{i,t-1}) + \ln(INVR_{i,t}) + \ln(S\&E_{i,t-lag}) + \log(pop_{i,t}) + \tau + a_i + \varepsilon_t$

The following pages reflect similar tables to those above. However in this case the results were done by taking the same data set and running panel modeling with the type 2 constructs.

Results for the Type 2 modeling are summarized, followed by a summary of all multi-country modeling.

4.2.2 Panel Multi-Country Results via Type 2 Modeling

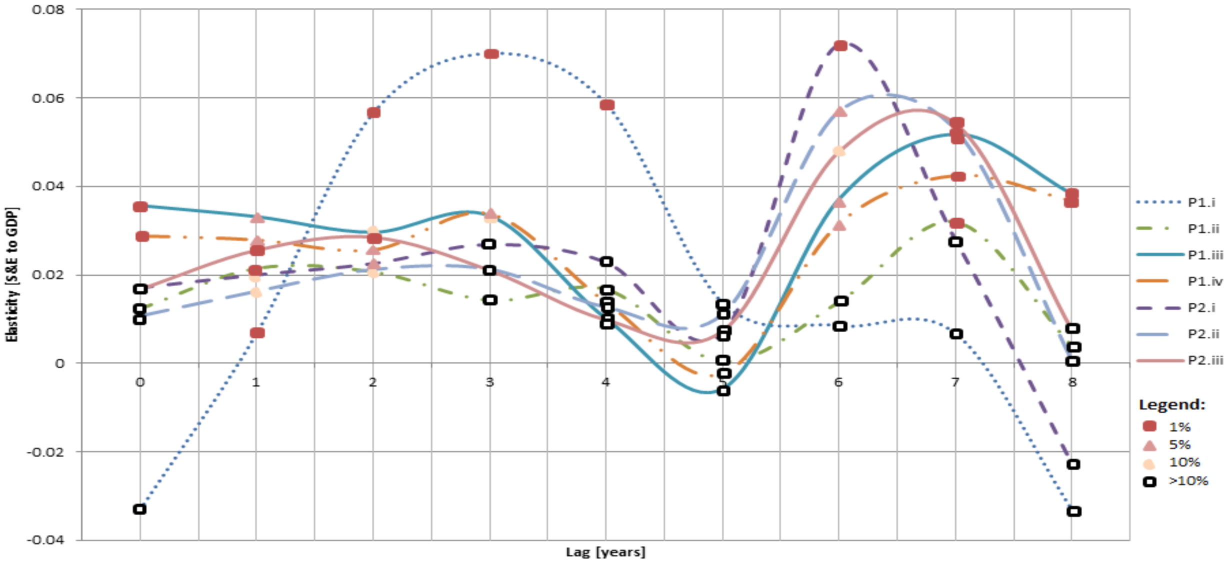


Figure 10: S&E graduate impact on GDP against years of lag since graduation for Models 1 and 2, Data Set 1

Each line represents a model variant. Other than the first model, which is the most simplistic contrasting model containing solely the prior year's GDP and S&E graduates at the various lags, all others indicate a later return on science and engineering graduates between year 6 and 7. As can be seen, the results are littered with statistically insignificant values throughout the years when the elasticity is approximately 0.02 or less.

Table 11: Results of Panel Model 2.ii for Data Set 1 across the range of lags

S&E Lag	GDP	Constant	GDP-1	INVR	UNEM	Con't below
0	Growth	-3.337962	-0.044158***	0.189415***	-0.049615***	…
1	Growth	-3.933416	-0.069143***	0.185828***	-0.052519***	…
2	Growth	-0.681186	-0.060876*	0.190176***	-0.047721***	…
3	Growth	-1.315992	-0.096871**	0.193495***	-0.045732***	…
4	Growth	-11.10694***	-0.155925***	0.208412***	-0.04299***	…
5	Growth	-6.420344	-0.14678***	0.189964***	-0.051672***	…
6	Growth	-8.924082*	-0.210635***	0.19982***	-0.047572***	…
7	Growth	-7.967657	-0.248642***	0.206149***	-0.036339*	…
8	Growth	1.985834	-0.205558***	0.252911***	-0.010779	…

OTH-GRAD	S&E	τ
0.006751	0.010696	0.001815
0.01359	0.01629*	0.002172
0.027623	0.021214**	0.000404
0.057206***	0.021272	0.000736
0.048489***	0.012703	0.006009***
0.057581***	0.01113	0.003586
0.048479*	0.05697**	0.004982*
0.038161**	0.052758***	0.004783
0.099072***	0.000543	-0.000472

where *, **, and *** are significant at 10%, 5%, and 1%, respectively, for model:

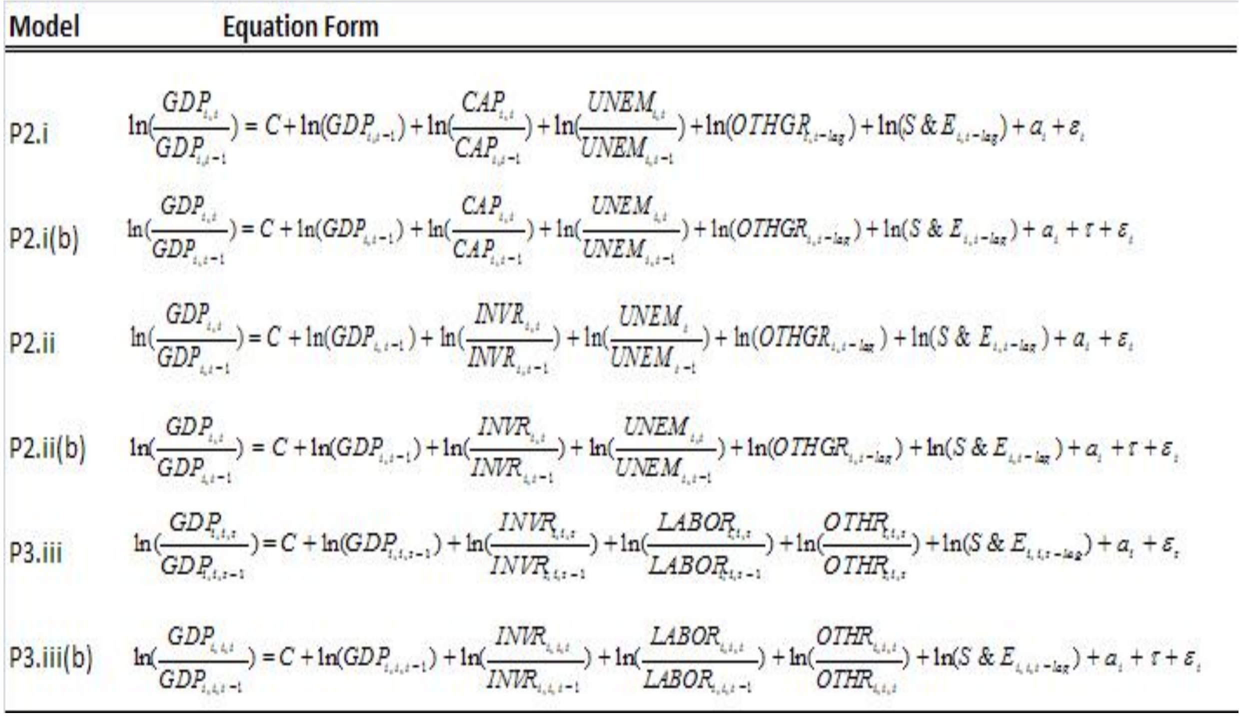
$$\ln(\frac{GDP_t}{GDP_{t-1}}) = C + \ln(GDP_{t-1}) + \ln(\frac{INVR_t}{INVR_{t-1}}) + \ln(\frac{UNEM_t}{UNEM_{t-1}}) + \ln(OTHGR_{t-lag}) + \ln(S\,\&\,E_{t-lag}) + \tau + \varepsilon_t$$

Table 12: S&E Coefficients and statistics for Panel Model 2 Variants for Data Set 1

Model	**S&E Coef**	**SE(S&E)**	**Model F-stat**	**Obs**	**Lag**
P2.i	0.072	0.024	11.840	105	6
P2.i(b)	0.068	0.024	11.620	105	6
P2.ii	0.062	0.030	23.500	110	7
P2.ii(b)	0.057	0.029	22.919	110	7
P3.iii	0.054	0.020	23.304	87	7
P3.iii(b)	0.053	0.020	22.273	87	7

Average 0.070 SD of Avg 0.003 ; for 6 year lag
Average 0.056 SD of Avg 0.004 ; for 7 year lag

The models per variant reported above are given in the following table on the next page in equation form.



Model	Equation Form
P2.i	$\ln(\frac{GDP_{i,t}}{GDP_{i,t-1}}) = C + \ln(GDP_{i,t-1}) + \ln(\frac{CAP_{i,t}}{CAP_{i,t-1}}) + \ln(\frac{UNEM_{i,t}}{UNEM_{i,t-1}}) + \ln(OTHGR_{i,t-lag}) + \ln(S\&E_{i,t-lag}) + a_i + \varepsilon_i$
P2.i(b)	$\ln(\frac{GDP_{i,t}}{GDP_{i,t-1}}) = C + \ln(GDP_{i,t-1}) + \ln(\frac{CAP_{i,t}}{CAP_{i,t-1}}) + \ln(\frac{UNEM_{i,t}}{UNEM_{i,t-1}}) + \ln(OTHGR_{i,t-lag}) + \ln(S\&E_{i,t-lag}) + a_i + \tau + \varepsilon_i$
P2.ii	$\ln(\frac{GDP_{i,t}}{GDP_{i,t-1}}) = C + \ln(GDP_{i,t-1}) + \ln(\frac{INVR_{i,t}}{INVR_{i,t-1}}) + \ln(\frac{UNEM_{t}}{UNEM_{t-1}}) + \ln(OTHGR_{i,t-lag}) + \ln(S\&E_{i,t-lag}) + a_i + \varepsilon_i$
P2.ii(b)	$\ln(\frac{GDP_{i,t}}{GDP_{i,t-1}}) = C + \ln(GDP_{i,t-1}) + \ln(\frac{INVR_{i,t}}{INVR_{i,t-1}}) + \ln(\frac{UNEM_{i,t}}{UNEM_{i,t-1}}) + \ln(OTHGR_{i,t-lag}) + \ln(S\&E_{i,t-lag}) + a_i + \tau + \varepsilon_i$
P3.iii	$\ln(\frac{GDP_{i,t,t}}{GDP_{i,t,t-1}}) = C + \ln(GDP_{i,t,t-1}) + \ln(\frac{INVR_{i,t,t}}{INVR_{i,t,t-1}}) + \ln(\frac{LABOR_{i,t,t}}{LABOR_{i,t,t-1}}) + \ln(\frac{OTHR_{i,t,t}}{OTHR_{i,t,t}}) + \ln(S\&E_{i,t,t-lag}) + a_i + \varepsilon_i$
P3.iii(b)	$\ln(\frac{GDP_{i,t,t}}{GDP_{i,t,t-1}}) = C + \ln(GDP_{i,t,t-1}) + \ln(\frac{INVR_{i,t,t}}{INVR_{i,t,t-1}}) + \ln(\frac{LABOR_{i,t,t}}{LABOR_{i,t,t-1}}) + \ln(\frac{OTHR_{i,t,t}}{OTHR_{i,t,t}}) + \ln(S\&E_{i,t,t-lag}) + a_i + \tau + \varepsilon_i$

4.2.3 Panel All-Country Results

The results presented next were run using all available countries as gathered from the various data sources listed in the Data Section previously. Given the vast diversity in educational and economic systems, it is not surprising that the results are largely inconclusive. Many of the points are statistically insignificant and the resulting elasticities are lower in magnitude than had been found previously. There is a general peeking around year 3 to 4 and 7 to 8, not too different from previously revealed trends, but such inference is weak given the statistics behind the results. The following graphs show the panel data run with all countries overlaid on the previous graph of the results from the first panel data set. To provide a bit more clarity, this is followed by another graph that shows the plots of the panel results for all countries against the plotted points from the first data set for contrast.

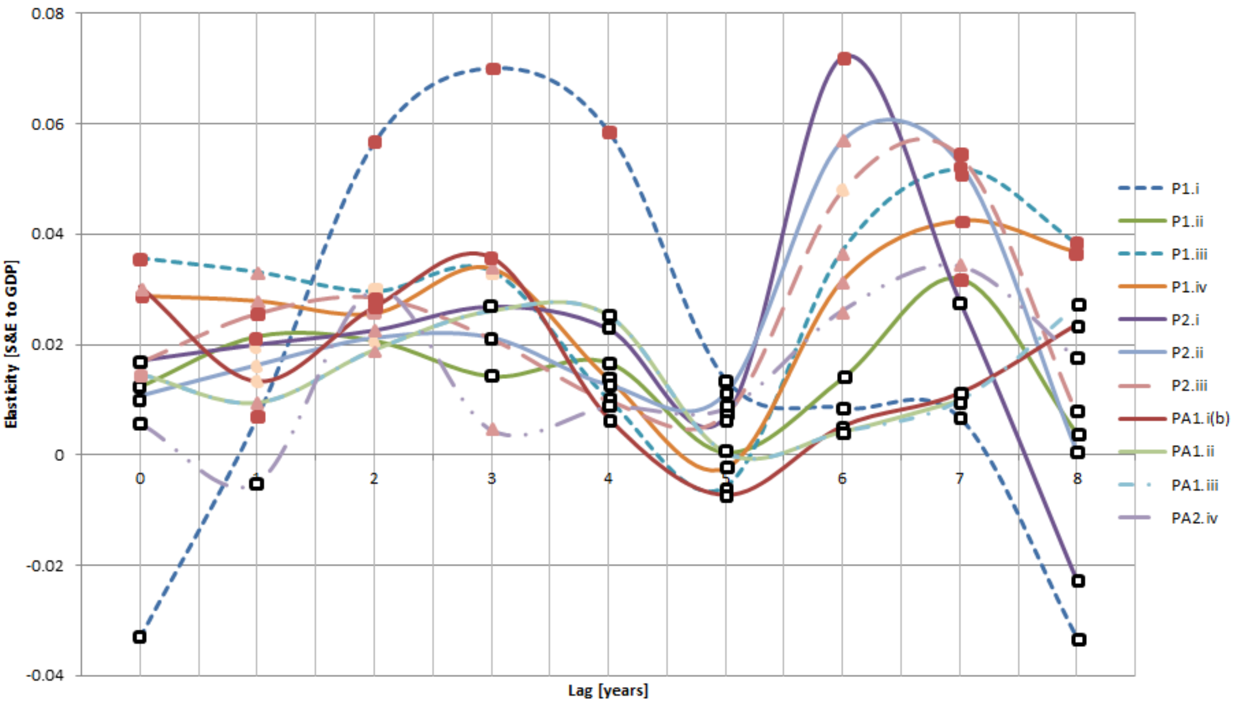


Figure 11: Plot of S&E impact on GDP per year of lag for all data sets

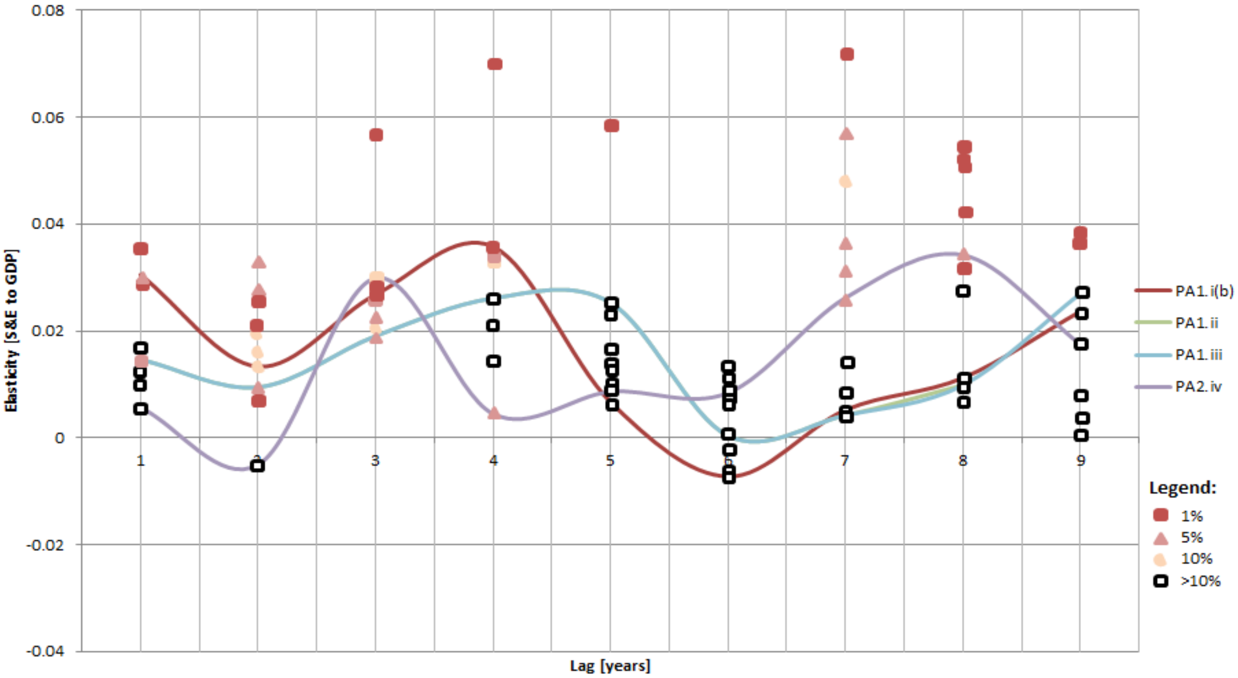


Figure 12: Plot of Panel with All Countries (Data set 2) against the points from Data Set 1

Table 13: S&E Coefficients with statistics for model variants using Data Set 2 (all countries)

Model	S&E Coef	SE(S&E)	Model F-stat	Obs	Lag	X Sections
P1.i	0.042	0.016	3355.667	534	3	101
P1.i(b)	0.070	0.019	1568.274	534	3	101
P1.ii	0.036	0.014	4.279	534	3	101
P1.ii(b)	0.026	0.013	6128.291	459	3	93
P1.iii	0.026	0.013	9.118	459	3	93
P2.i	0.034	0.014	11.292	164	7	51

Average 0.040 SD of Avg 0.018 ; done for 3 year lag only

Where the models are:

Model	Equation Form
P1.i	$\ln(GDP_t) = C + \ln(GDP_{t-1}) + \ln(S\&E_{t-lag}) + a_i + \varepsilon_t$
P1.i(b)	$\ln(GDP_t) = C + \ln(GDP_{t-1}) + \ln(S\&E_{t-lag}) + a_i + \tau + \varepsilon_t$
P1.ii	$\ln(\frac{GDP_{i,t}}{GDP_{i,t}}) = C + \ln(GDP_{i,t-1}) + \ln(S\&E_{i,t-lag}) + a_i + \tau + \varepsilon_t$
P1.ii(b)	$\ln(GDP_{i,t}) = \ln(GDP_{i,t-1}) + \ln(CAP_{i,t}) + \ln(S\&E_{i,t-lag}) + a_i + \varepsilon_t$
P1.iii	$\ln(\frac{GDP_{i,t}}{GDP}) = \ln(GDP_{i,t-1}) + \ln(CAP_{i,t}) + \ln(S\&E_{i,t-lag}) + \tau + a_i + \varepsilon_t$
P2.i	$\ln(\frac{GDP_t}{GDP_{t-1}}) = C + \ln(GDP_{t-1}) + \ln(\frac{CAP_t}{CAP_{t-1}}) + \ln(\frac{UNEM_t}{UNEM_{t-1}}) + \ln(S\&E_{i,t-lag}) + \ln(\frac{POP_{i,t}}{POP_{i,t}}) + a_i + \tau + \varepsilon_t$

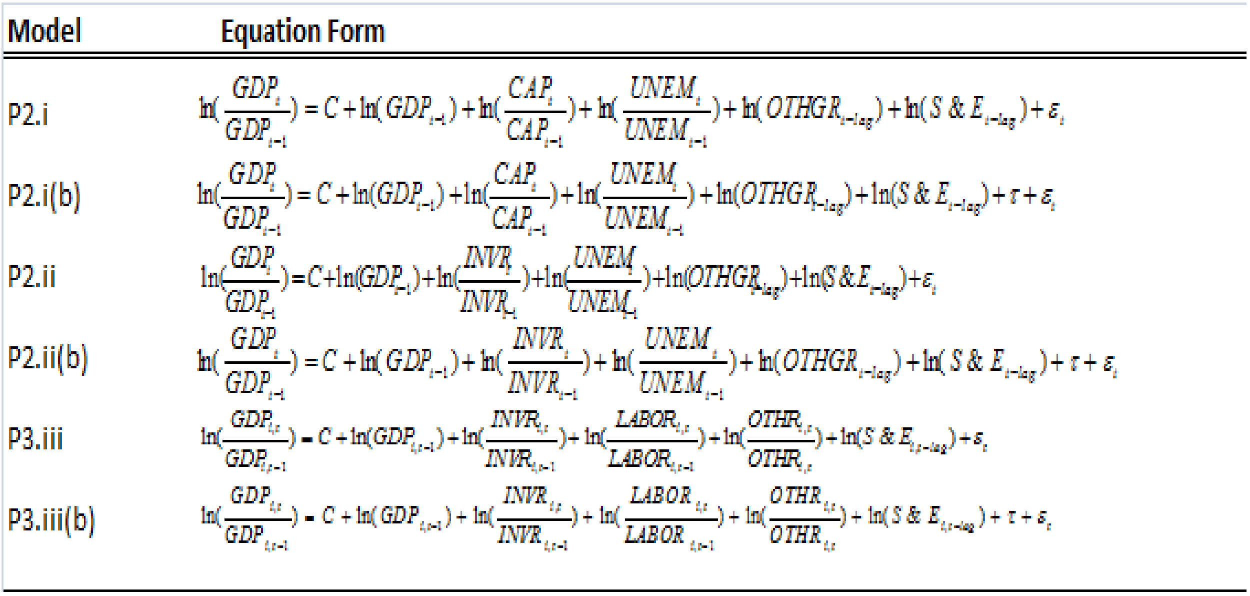
The model two results, as with the USA-Only analysis result in larger elasticities on the average.

Table 14: S&E coefficients with statistics for type 2 panel models using data set 2 (all countries)

Model	S&E Coef	SE(S&E)	Model F-stat	Obs	Lag
P2.i	0.072	0.024	11.840	105	6
P2.i(b)	0.068	0.024	11.620	105	6
P2.ii	0.062	0.030	23.500	110	7
P2.ii(b)	0.057	0.029	22.919	110	7
P3.iii	0.054	0.020	23.304	87	7
P3.iii(b)	0.053	0.020	22.273	87	7

Average 0.061 SD of Avg 0.008

Where the models are:



Model	Equation Form
P2.i	$\ln(\frac{GDP_t}{GDP_{t-1}}) = C + \ln(GDP_{t-1}) + \ln(\frac{CAP_t}{CAP_{t-1}}) + \ln(\frac{UNEM_t}{UNEM_{t-1}}) + \ln(OTHGR_{t-lag}) + \ln(S\,\&\,E_{t-lag}) + \varepsilon_t$
P2.i(b)	$\ln(\frac{GDP_t}{GDP_{t-1}}) = C + \ln(GDP_{t-1}) + \ln(\frac{CAP_t}{CAP_{t-1}}) + \ln(\frac{UNEM_t}{UNEM_{t-1}}) + \ln(OTHGR_{t-lag}) + \ln(S\,\&\,E_{t-lag}) + \tau + \varepsilon_t$
P2.ii	$\ln(\frac{GDP_t}{GDP_{t-1}}) = C + \ln(GDP_{t-1}) + \ln(\frac{INVR_t}{INVR_{t-1}}) + \ln(\frac{UNEM_t}{UNEM_{t-1}}) + \ln(OTHGR_{t-lag}) + \ln(S\,\&\,E_{t-lag}) + \varepsilon_t$
P2.ii(b)	$\ln(\frac{GDP_t}{GDP_{t-1}}) = C + \ln(GDP_{t-1}) + \ln(\frac{INVR_t}{INVR_{t-1}}) + \ln(\frac{UNEM_t}{UNEM_{t-1}}) + \ln(OTHGR_{t-lag}) + \ln(S\,\&\,E_{t-lag}) + \tau + \varepsilon_t$
P3.iii	$\ln(\frac{GDP_{i,t}}{GDP_{i,t-1}}) = C + \ln(GDP_{i,t-1}) + \ln(\frac{INVR_{i,t}}{INVR_{i,t-1}}) + \ln(\frac{LABOR_{i,t}}{LABOR_{i,t-1}}) + \ln(\frac{OTHR_{i,t}}{OTHR_{i,t}}) + \ln(S\,\&\,E_{i,t-lag}) + \varepsilon_t$
P3.iii(b)	$\ln(\frac{GDP_{i,t}}{GDP_{i,t-1}}) = C + \ln(GDP_{i,t-1}) + \ln(\frac{INVR_{i,t}}{INVR_{i,t-1}}) + \ln(\frac{LABOR_{i,t}}{LABOR_{i,t-1}}) + \ln(\frac{OTHR_{i,t}}{OTHR_{i,t}}) + \ln(S\,\&\,E_{i,t-lag}) + \tau + \varepsilon_t$

4.3 Summary of Panel Results

For the all countries or OECD countries modeling, the lag of S&E graduates to maximum economic impact tended to be later than the USA only modeling. This could be inferred as either a higher quality of education or preparation of S&E graduates, or it could be that industry is better able to receive and extract production from S&E graduates in the USA. The modeling significance was spottier than USA only modeling and rendered more S&E points insignificant, which weakens the ability to contrast the USA and other countries. That said, it does seem that the impact of S&E graduates is lower overall (average 0.06) than in the USA alone (average 0.2) as the elasticities are lower. The result is perhaps not surprising given the large variances in educational systems, graduates, economic statuses and so on for the different countries included.

4.4 Alternative Analyses of the Study

In addition to the overall goal of whether a link between S&E and economic factors exist, the data gathered lent itself to a few other models. The first was whether there is a link between patents and S&E, which resulted in statistically significant models across the range of lagged years from graduation and provided an elasticity of 1.97 on the average, indicating a 1% increase in S&E will result in a 1.97% increase in US patents. Given the educational trends presented previously, some correlation may be made in patent trending; where in 2009, non-U.S. companies gained the majority, 51%, of U.S. patents (Gathering Storm Committe of the National Academy of Sciences, 2010).

Using model variants of Type 1 and Type 2 using the OECD data set, the economic impact between S&E and humanities was also modeled. In this case, half of the S&E models (per given year of lag) were significant statistically and resulted in an average elasticity with GDP of 0.04. The humanities graduates for that same range resulted in an elasticity of -0.07 but where typically statistically insignificant. An example output at 3 years of lag between engineering, humanities and social science is provided below. Most often, the modeling did not result in statistically significant coefficients for each discipline of graduate and thus correlation inference is limited.

Table 15: cross discipline panel output for oecd data set at 3 year lag

Dependent Variable: LOG(GDP1/GDP1(-1))
Method: Panel Least Squares
Date: 09/08/11   Time: 17:54
Sample (adjusted): 2001 2009
Periods included: 9
Cross-sections included: 12
Total panel (unbalanced) observations: 100
White cross-section standard errors & covariance (d.f. corrected)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.147084	0.210182	-0.699794	0.486
LOG(GDP1(-1))	-0.027024	0.021212	-1.274	0.2063
LOG(CAP/CAP(-1))	0.166587	0.06825	2.44084	0.0168
LOG(UNEM/UNEM(-1))	-0.090567	0.038452	-2.355306	0.0209
LOG(ENGN(-3))	0.063539	0.019311	3.29024	0.0015
LOG(HUMNO(-3))	-0.013642	0.01755	-0.777337	0.4392
LOG(SOCSN(-3))	-0.005972	0.011729	-0.5092	0.612

Effects Specification

Cross-section fixed (dummy variables)

R-squared	0.647185	Mean dependent var	0.040896
Adjusted R-squared	0.57404	S.D. dependent var	0.038757
S.E. of regression	0.025295	Akaike info criterion	-4.35487
Sum squared resid	0.052467	Schwarz criterion	-3.88594
Log likelihood	235.7435	Hannan-Quinn criter.	-4.165085
F-statistic	8.84801	Durbin-Watson stat	1.849935
Prob(F-statistic)	0		

In kind with the modeling done solely of the USA, the Chinese models were run and resulted in a general trend in which maximum economic impact occurred in year 2 to 2.5 years as compared to the 3.5 for the USA. However, fewer of the points in the models were statistically significant, as can be seen and exemplified in the table provided below. For all models and all points (years of lag), the average elasticity between S&E graduates and GDP was 0.05 with a standard deviation of 0.07, though these points include large and insignificant coefficients of both polarities. Of those years per variant that were statistically significant, the average elasticity was higher at 0.07 with a lower deviation of 0.009 and were nearly always within the first three years of lag.

Table 16: results of the china-only model for range of lagged years 0 to 8

China Only: $$\ln\left(\frac{GDP_t}{GDP_{t-1}}\right) = C + \ln(GDP_{t-1}) + \ln\left(\frac{CAP_t}{CAP_{t-1}}\right) + \ln\left(\frac{UNEM_t}{UNEM_{t-1}}\right) + \ln\left(\frac{S\&E_t}{S\&E_{t-1}}\right) + \tau + \varepsilon_t$$

S&E Lag	GDP	Constant	GDP-1	CAP	UNEM	S&E	τ
0	Growth	13.89437	0.019678	0.307834***	-0.105475**	0.055673**	-0.007341
1	Growth	30.87903	0.098668	0.571764***	-0.063488	0.060277**	-0.016176
2	Growth	26.38462	0.077419	0.305601***	-0.119133***	0.070759***	-0.013895
3	Growth	28.19985	0.106051	0.580397***	-0.174017**	0.042912	-0.014747
4	Growth	33.27913	0.154666	0.284051***	-0.130245**	0.025843	-0.01735
5	Growth	58.1697	0.182998	0.604619***	-0.314084**	0.16024	-0.030749
6	Growth	27.81779	0.141341	0.37256***	-0.206525**	0.00965	-0.014471
7	Growth	33.3186	0.241639	0.789342**	-0.20414	-0.135091	-0.016738
8	Growth	58.89693	0.221157	0.449616***	-0.057499	0.157698	-0.031227

5. Conclusion

There are clear trends in the USA with regard to a stagnant growth in S&E, particularly engineering, and in greater contrast when considered per capita. Meanwhile certain Asian counties, such as China and Taiwan, have experienced growth in S&E graduates beyond mere population growth. India presents a similar case. This has caught the eye of alarmists and so discussions have ensued over offshoring, national security, economic loss and future impact. Alarmists and proponents of policies promoting more science, engineering and math have pointed out the trends in overseas growth and US offshoring with a flurry of statistics and data. The more conservative or reserved in the discussion believe the numbers reported by China, India and others are either exaggerated or not directly comparable. The work presented herein does not settle that debate but does examine whether a statistical link exists between graduates in engineering and economic growth, such as GDP or national income. This work also found a statistical link between the number of S&E graduates and patents.

The initial modeling focused solely on the USA and showed a statistically significant impact on the economy from S&E graduates. Type 1 modeling resulted in an average elasticity of 0.116 and Type 2 an average of 0.264 between GDP and S&E Graduates. This does seem to be of import for those concerned over relatively stagnant engineering growth that dampens S&E growth of graduates over the past couple of decades. A large portion of the many variants that were regressed showed a maximum impact occurred approximately 3.5 years to 4 years after graduation. The panel models were run for all countries available and for OECD, which showed a maximum impact further away from graduation. In the all-countries case, it appears to be centered near year 7. The elasticities of these various models were lower than the USA-Only modeling, where Type 1 models averaged 0.04 and Type 2, 0.06 respectively, for the data set containing all available countries. The statistical evidence was less robust for the all-countries regressions but indicates that the USA is able to get more on average from S&E at a quicker pace than other countries. However, previous studies of individual countries such as that by Lin

(2004) showed that Taiwanese S&E graduates had a larger impact than the one found herein for the USA. Also, regression analysis done with just Chinese data showed that the maximum impact gained from S&E graduates in China was slightly quicker than the USA. As such, it is likely that the lag between impact and the magnitude of that impact varies greatly amongst countries and the USA results are not at either extreme for either magnitude or lag.

The results could be seen as an affirmation for the alarmists that wish to use public policy, social influences, media, etc to generate a greater interest in science and engineering among the youth of the nation. However, determining how much interest, how many S&E graduates are truly needed and similar assessments would require a study of markets, both domestic and international, and demand for such as unbridled growth in any discipline will reach points of ineffectiveness or even become a detriment. As such, it would have to be combined with strategic planning and initiatives so that S&E graduates have a place to produce within industry.

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Appendix A: summary Results for model 1 variants across range of lag

Model 1.i Results:

$$\log(GDP_t) = C + \log(GDP_{t-1}) + \log(S\&E_{t-lag}) + \varepsilon_t$$

S&E Lag	GDP	Constant	GDP-1	S&E		Note
0	Value	0.001498	0.970548*	0.072373*		White heteroskedasticity-consistent standard errors & covariance
1	Value	-0.125627	0.964828***	0.095536***		White heteroskedasticity-consistent standard errors & covariance
2	Value	-0.091222	0.960978***	0.101821***		White heteroskedasticity-consistent standard errors & covariance
3	Value	-0.262659	0.954363***	0.130614***		White heteroskedasticity-consistent standard errors & covariance
4	Value	-0.257912	0.95152***	0.136962***		White heteroskedasticity-consistent standard errors & covariance
5	Value	0.165545	0.956154***	0.093187***		White heteroskedasticity-consistent standard errors & covariance
6	Value	0.374489	0.957862***	0.072928***		White heteroskedasticity-consistent standard errors & covariance
7	Value	0.436791	0.956759***	0.070666**		White heteroskedasticity-consistent standard errors & covariance
8	Value	0.454209	0.957224***	0.068293		White heteroskedasticity-consistent standard errors & covariance

where *, **, and *** are significant at 10%, 5%, and 1%, respectively.

Model 1.i(b) Results:

$$\log(GDP_t) = C + \log(GDP_{t-1}) + \log(S\&E_{t-lag}) + \tau + \varepsilon_t$$

S&E Lag	GDP	Constant	GDP-1	S&E	τ	Note
0	Value	6.578393	1.020211***	0.120994***	-0.004346*	White heteroskedasticity-consistent standard errors & covariance
1	Value	4.80368	1.003819***	0.114669***	-0.003172	White heteroskedasticity-consistent standard errors & covariance
2	Value	2.769274	0.984232***	0.109779***	-0.001829	White heteroskedasticity-consistent standard errors & covariance
3	Value	1.473851	0.968944***	0.133276***	-0.001103	White heteroskedasticity-consistent standard errors & covariance
4	Value	-0.578882	0.948724***	0.136957***	0.000202	White heteroskedasticity-consistent standard errors & covariance
5	Value	-3.032102	0.927287***	0.097542***	0.002003	White heteroskedasticity-consistent standard errors & covariance
6	Value	-4.792439	0.909585***	0.084632***	0.00323*	White heteroskedasticity-consistent standard errors & covariance
7	Value	-6.802641**	0.886607***	0.092939***	0.004526**	White heteroskedasticity-consistent standard errors & covariance
8	Value	-8.330841***	0.868658***	0.102755**	0.005495***	White heteroskedasticity-consistent standard errors & covariance

where *, **, and *** are significant at 10%, 5%, and 1%, respectively.

Model 1.ii(b) Results:

$$\ln(\frac{GDP_t}{GDP_{t-1}}) = C + \ln(GDP_{t-1}) + \ln(S\&E_{t-lag}) + \tau + \varepsilon_t$$

S&E Lag	GDP	Constant	GDP-1	S&E	τ	Note
0	Growth	6.578393*	0.020211	0.120994***	-0.004346*	White heteroskedasticity-consistent standard errors & covariance
1	Growth	4.80368	0.003819	0.114669***	-0.003172	White heteroskedasticity-consistent standard errors & covariance
2	Growth	2.769274	-0.015768	0.109779***	-0.001829	White heteroskedasticity-consistent standard errors & covariance
3	Growth	1.473851	-0.031056	0.133276***	-0.001103	White heteroskedasticity-consistent standard errors & covariance
4	Growth	-0.578882	-0.051276*	0.136957***	0.000202	White heteroskedasticity-consistent standard errors & covariance
5	Growth	-3.032102	-0.072713**	0.097542***	0.002003	White heteroskedasticity-consistent standard errors & covariance
6	Growth	-4.792439	-0.090415***	0.084632***	0.00323*	White heteroskedasticity-consistent standard errors & covariance
7	Growth	-6.802641**	-0.113393***	0.092939***	0.004526**	White heteroskedasticity-consistent standard errors & covariance
8	Growth	-8.330841***	-0.131342***	0.102755**	0.005495***	White heteroskedasticity-consistent standard errors & covariance

where *, **, and *** are significant at 10%, 5%, and 1%, respectively.

Model 1.iii Results:

$$\ln(\frac{GDP_t}{GDP_{t-1}}) = C + \ln(GDP_{t-1}) + \ln(S \& E_{t-lag}) + \ln(INVR_t) + \varepsilon_t$$

S&E Lag	GDP	Constant	GDP-1	INVR	S&E	Note
0	Growth	1.02255***	-0.191454***	0.158018***	0.020844	White heteroskedasticity-consistent standard errors & covariance
1	Growth	0.736102**	-0.184787***	0.145091***	0.056068*	White heteroskedasticity-consistent standard errors & covariance
2	Growth	0.764954***	-0.180763***	0.138688***	0.058582***	White heteroskedasticity-consistent standard errors & covariance
3	Growth	0.559663**	-0.174057***	0.126732***	0.085385***	White heteroskedasticity-consistent standard errors & covariance
4	Growth	0.582966**	-0.180573***	0.130035***	0.091473***	White heteroskedasticity-consistent standard errors & covariance
5	Growth	0.831817***	-0.189153***	0.138223***	0.073946***	White heteroskedasticity-consistent standard errors & covariance
6	Growth	0.943762***	-0.201208***	0.147456***	0.072871***	White heteroskedasticity-consistent standard errors & covariance
7	Growth	1.062721***	-0.207396***	0.15198***	0.068001***	White heteroskedasticity-consistent standard errors & covariance
8	Growth	1.247708***	-0.212458***	0.158125***	0.051761	White heteroskedasticity-consistent standard errors & covariance

where *, **, and *** are significant at 10%, 5%, and 1%, respectively.

Model 1.iv Results:

$$\ln(GDP_t) = \ln(GDP_{t-1}) + \ln(INVR_t) + \ln(S\&E_{t-lag}) + \varepsilon_t$$

S&E Lag	GDP	Constant	GDP-1	INVR	S&E	Note
0	Value	1.02255**	0.808546***	0.158018***	0.020844	White heteroskedasticity-consistent standard errors & covariance
1	Value	0.736102**	0.815213***	0.145091***	0.056068*	White heteroskedasticity-consistent standard errors & covariance
2	Value	0.764954***	0.819237***	0.138688***	0.058582***	White heteroskedasticity-consistent standard errors & covariance
3	Value	0.559663***	0.825943***	0.126732***	0.085385***	White heteroskedasticity-consistent standard errors & covariance
4	Value	0.582966**	0.819427***	0.130035***	0.091473***	White heteroskedasticity-consistent standard errors & covariance
5	Value	0.831817***	0.810847***	0.138223***	0.073946***	White heteroskedasticity-consistent standard errors & covariance
6	Value	0.943762***	0.798792***	0.147456***	0.072871***	White heteroskedasticity-consistent standard errors & covariance
7	Value	1.062721***	0.792604***	0.15198***	0.068001***	White heteroskedasticity-consistent standard errors & covariance
8	Value	1.247708***	0.787542***	0.158125***	0.051761	White heteroskedasticity-consistent standard errors & covariance

where *, **, and *** are significant at 10%, 5%, and 1%, respectively.

Model 2.i Results:

$$\ln(\frac{GDP_t}{GDP_{t-1}}) = C + \ln(\frac{CAP_t}{CAP_{t-1}}) + \ln(\frac{UNEM_t}{UNEM_{t-1}}) + \ln(GRAD_{t-lag}) + \ln(S\&E_{t-lag}) + \varepsilon_t$$

S&E Lag	GDP	Constant	CAP	UNEM	GRADS	S&E	Note
0	Growth	0.9949**	0.100096	-0.053948	-0.117734	0.054871	White heteroskedasticity-consistent standard errors & covariance
1	Growth	1.081892**	0.128581	-0.04382	-0.176418	0.111798	White heteroskedasticity-consistent standard errors & covariance
2	Growth	0.336275	0.022768	-0.124895***	0.157783*	-0.192658**	White heteroskedasticity-consistent standard errors & covariance
3	Growth	1.184332**	0.173628*	-0.04096	-0.286461***	0.223288**	White heteroskedasticity-consistent standard errors & covariance
4	Growth	1.158689**	0.168877**	-0.059648*	-0.333666***	0.276612***	White heteroskedasticity-consistent standard errors & covariance
5	Growth	1.041023**	0.177479**	-0.067576*	-0.385381***	0.34203***	White heteroskedasticity-consistent standard errors & covariance
6	Growth	0.905352**	0.155172*	-0.069667**	-0.366741**	0.332361*	White heteroskedasticity-consistent standard errors & covariance
7	Growth	0.728658**	0.146776*	-0.056672*	-0.337678*	0.314551*	White heteroskedasticity-consistent standard errors & covariance
8	Growth	0.705809**	0.14327*	-0.040455	-0.292435*	0.26705*	White heteroskedasticity-consistent standard errors & covariance

where *, **, and *** are significant at 10%, 5%, and 1%, respectively.

Model 2.i(b) Results

S&E Lag	GDP	Constant	CAP	UNEM	GRADS	S&E	Note
0	Growth	5.961706***	0.096627	-0.055141	0.096308	0.076491	White heteroskedasticity-consistent standard errors & covariance
1	Growth	5.929141	0.142583*	-0.022053	0.006931	0.175887	White heteroskedasticity-consistent standard errors & covariance
2	Growth	5.852027	0.200229**	0.00164	-0.103421	0.299034**	White heteroskedasticity-consistent standard errors & covariance
3	Growth	5.368775	0.189246**	-0.022653	-0.090662	0.278025***	White heteroskedasticity-consistent standard errors & covariance
4	Growth	5.471734	0.170943**	-0.053755	-0.115494	0.338571***	White heteroskedasticity-consistent standard errors & covariance
5	Growth	6.689759**	0.144065*	-0.089256**	-0.085719	0.43579***	White heteroskedasticity-consistent standard errors & covariance
6	Growth	6.270494***	0.121795**	-0.102824***	-0.044618	0.399039***	White heteroskedasticity-consistent standard errors & covariance
7	Growth	5.349208***	0.108287*	-0.096418***	0.049644	0.269776**	White heteroskedasticity-consistent standard errors & covariance
8	Growth	4.458181***	0.123824**	-0.082343***	0.088436	0.16641	White heteroskedasticity-consistent standard errors & covariance

where *, **, and *** are significant at 10%, 5%, and 1%, respectively.

Model 2.ii Results:

$$\ln(\frac{GDP_t}{GDP_{t-1}}) = C + \ln(GDP_{t-1}) + \ln(\frac{CAP_t}{CAP_{t-1}}) + \ln(\frac{UNEM_t}{UNEM_{t-1}}) + \ln(OTHGR_{t-lag}) + \ln(S\&E_{t-lag}) + \varepsilon_t$$

S&E Lag	GDP	Constant	GDP-1	CAP	UNEM	OTH-GRAD	S&E	Note
0	Growth	-0.176601	-0.079402**	0.080451	-0.066717**	0.127173	0.066134	White heteroskedasticity-consistent
1	Growth	-0.190763	-0.074348**	0.113844	-0.036724	0.048713	0.138838	White heteroskedasticity-consistent
2	Growth	-0.311479	-0.074162*	0.175727**	-0.00876	-0.040628	0.242496**	White heteroskedasticity-consistent
3	Growth	-0.505253	-0.076048*	0.173426**	-0.026711	-0.033456	0.254663***	White heteroskedasticity-consistent
4	Growth	-0.788578	-0.078817**	0.156789*	-0.058452*	-0.060568	0.312232***	White heteroskedasticity-consistent
5	Growth	-1.254481**	-0.086857***	0.127747**	-0.092052***	-0.063964	0.371246***	White heteroskedasticity-consistent
6	Growth	-1.240457**	-0.079555***	0.105213**	-0.100464***	-0.031604	0.319274***	White heteroskedasticity-consistent
7	Growth	-1.14547**	-0.069916***	0.093721	-0.093632***	0.028112	0.226527***	White heteroskedasticity-consistent
8	Growth	-0.890368*	-0.060959***	0.105422*	-0.083732***	0.064063	0.147836*	White heteroskedasticity-consistent

where *, **, and *** are significant at 10%, 5%, and 1%, respectively.

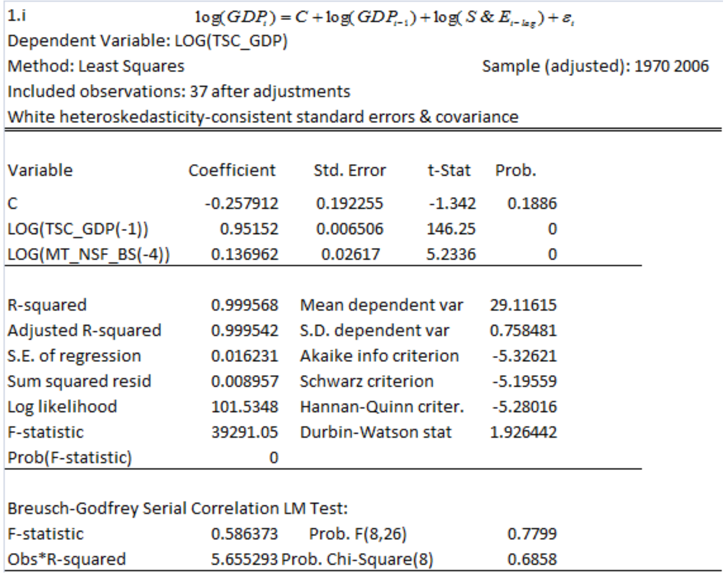
Model 2.iii Results:

$$\ln(\frac{GDP_t}{GDP_{t-1}}) = C + \ln(GDP_{t-1}) + \ln(\frac{INVR_t}{INVR_{t-1}}) + \ln(\frac{UNEM_t}{UNEM_{t-1}}) + \ln(OTHGR_{t-lag}) + \ln(S\&E_{t-lag}) + \varepsilon_t$$

S&E Lag	GDP	Constant	GDP-1	INVR	UNEM	OTH-GRAD	S&E	Note
0	Growth	0.29816	-0.035304*	0.213187***	0.012196	-0.022844	0.085656	White heteroskedasticity-consistent
1	Growth	0.171315	-0.038032**	0.240023***	0.037688	-0.088522	0.171324**	White heteroskedasticity-consistent
2	Growth	-0.100426	-0.047974***	0.236365***	0.036498	-0.091967*	0.219269***	White heteroskedasticity-consistent
3	Growth	-0.350093	-0.05482***	0.232556***	0.018904	-0.067248	0.228613***	White heteroskedasticity-consistent
4	Growth	-0.567232*	-0.059792***	0.203092***	-0.012858	-0.043571	0.232364***	White heteroskedasticity-consistent
5	Growth	-0.869753**	-0.068038***	0.159542***	-0.044455	-0.005824	0.235587***	White heteroskedasticity-consistent
6	Growth	-0.800777**	-0.061717***	0.150895***	-0.049601*	0.012363	0.196504***	White heteroskedasticity-consistent
7	Growth	-0.694174*	-0.054229***	0.147741***	-0.045509*	0.048955	0.132232**	White heteroskedasticity-consistent
8	Growth	-0.420113	-0.043979***	0.179531***	-0.026904	0.05707	0.078325	White heteroskedasticity-consistent

where *, **, and *** are significant at 10%, 5%, and 1%, respectively.

Statistically Detailed Outputs of Model 1 at 4 year lag – USA only regression



1.i $\log(GDP_t) = C + \log(GDP_{t-1}) + \log(S \& E_{t-lag}) + \varepsilon_t$

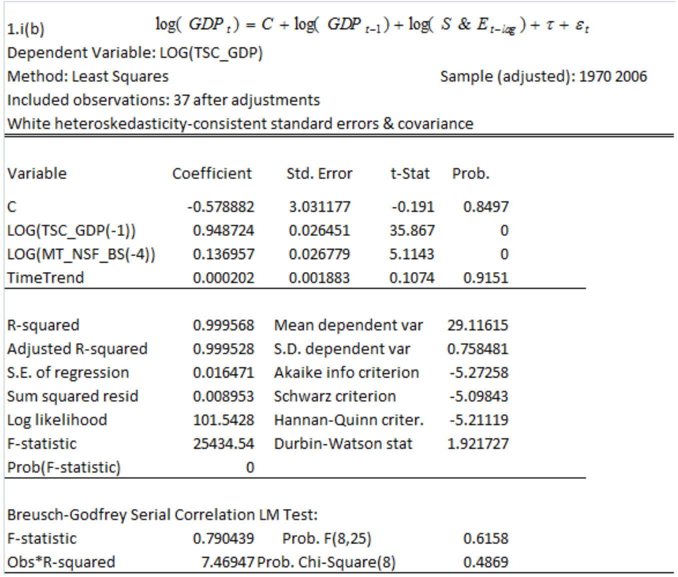
Dependent Variable: LOG(TSC_GDP)
Method: Least Squares Sample (adjusted): 1970 2006
Included observations: 37 after adjustments
White heteroskedasticity-consistent standard errors & covariance

Variable	Coefficient	Std. Error	t-Stat	Prob.
C	-0.257912	0.192255	-1.342	0.1886
LOG(TSC_GDP(-1))	0.95152	0.006506	146.25	0
LOG(MT_NSF_BS(-4))	0.136962	0.02617	5.2336	0

R-squared	0.999568	Mean dependent var	29.11615
Adjusted R-squared	0.999542	S.D. dependent var	0.758481
S.E. of regression	0.016231	Akaike info criterion	-5.32621
Sum squared resid	0.008957	Schwarz criterion	-5.19559
Log likelihood	101.5348	Hannan-Quinn criter.	-5.28016
F-statistic	39291.05	Durbin-Watson stat	1.926442
Prob(F-statistic)	0		

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.586373	Prob. F(8,26)	0.7799
Obs*R-squared	5.655293	Prob. Chi-Square(8)	0.6858



1.i(b) $\log(GDP_t) = C + \log(GDP_{t-1}) + \log(S \& E_{t-lag}) + \tau + \varepsilon_t$

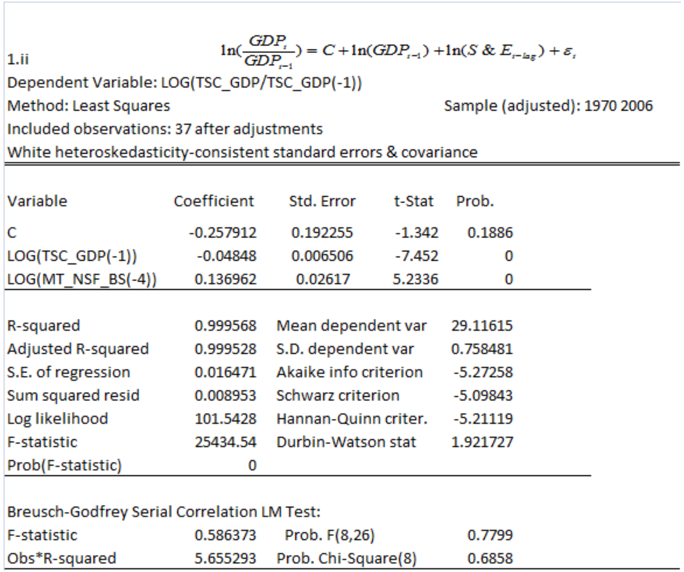
Dependent Variable: LOG(TSC_GDP)
Method: Least Squares Sample (adjusted): 1970 2006
Included observations: 37 after adjustments
White heteroskedasticity-consistent standard errors & covariance

Variable	Coefficient	Std. Error	t-Stat	Prob.
C	-0.578882	3.031177	-0.191	0.8497
LOG(TSC_GDP(-1))	0.948724	0.026451	35.867	0
LOG(MT_NSF_BS(-4))	0.136957	0.026779	5.1143	0
TimeTrend	0.000202	0.001883	0.1074	0.9151

R-squared	0.999568	Mean dependent var	29.11615
Adjusted R-squared	0.999528	S.D. dependent var	0.758481
S.E. of regression	0.016471	Akaike info criterion	-5.27258
Sum squared resid	0.008953	Schwarz criterion	-5.09843
Log likelihood	101.5428	Hannan-Quinn criter.	-5.21119
F-statistic	25434.54	Durbin-Watson stat	1.921727
Prob(F-statistic)	0		

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.790439	Prob. F(8,25)	0.6158
Obs*R-squared	7.46947	Prob. Chi-Square(8)	0.4869



1.ii $\ln(\frac{GDP_t}{GDP_{t-1}}) = C + \ln(GDP_{t-1}) + \ln(S \& E_{t-lag}) + \varepsilon_t$

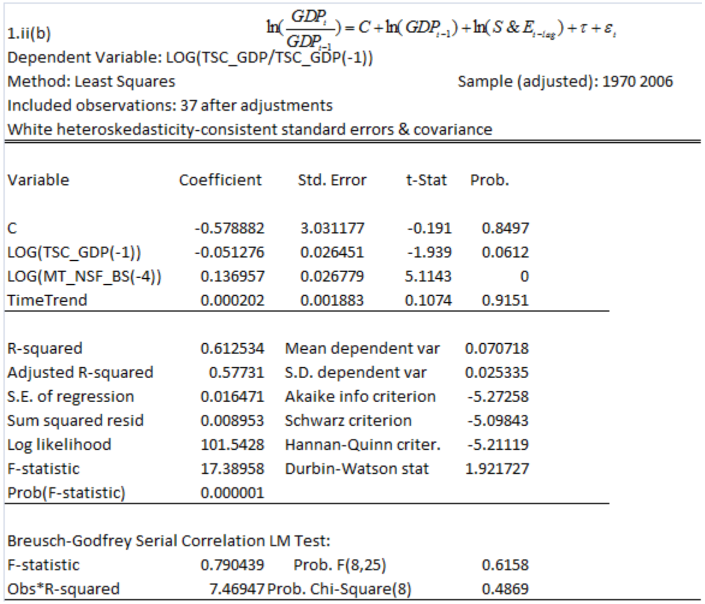
Dependent Variable: LOG(TSC_GDP/TSC_GDP(-1))
Method: Least Squares Sample (adjusted): 1970 2006
Included observations: 37 after adjustments
White heteroskedasticity-consistent standard errors & covariance

Variable	Coefficient	Std. Error	t-Stat	Prob.
C	-0.257912	0.192255	-1.342	0.1886
LOG(TSC_GDP(-1))	-0.04848	0.006506	-7.452	0
LOG(MT_NSF_BS(-4))	0.136962	0.02617	5.2336	0

R-squared	0.999568	Mean dependent var	29.11615
Adjusted R-squared	0.999528	S.D. dependent var	0.758481
S.E. of regression	0.016471	Akaike info criterion	-5.27258
Sum squared resid	0.008953	Schwarz criterion	-5.09843
Log likelihood	101.5428	Hannan-Quinn criter.	-5.21119
F-statistic	25434.54	Durbin-Watson stat	1.921727
Prob(F-statistic)	0		

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.586373	Prob. F(8,26)	0.7799
Obs*R-squared	5.655293	Prob. Chi-Square(8)	0.6858



1.ii(b) $\ln(\frac{GDP_t}{GDP_{t-1}}) = C + \ln(GDP_{t-1}) + \ln(S \& E_{t-lag}) + \tau + \varepsilon_t$

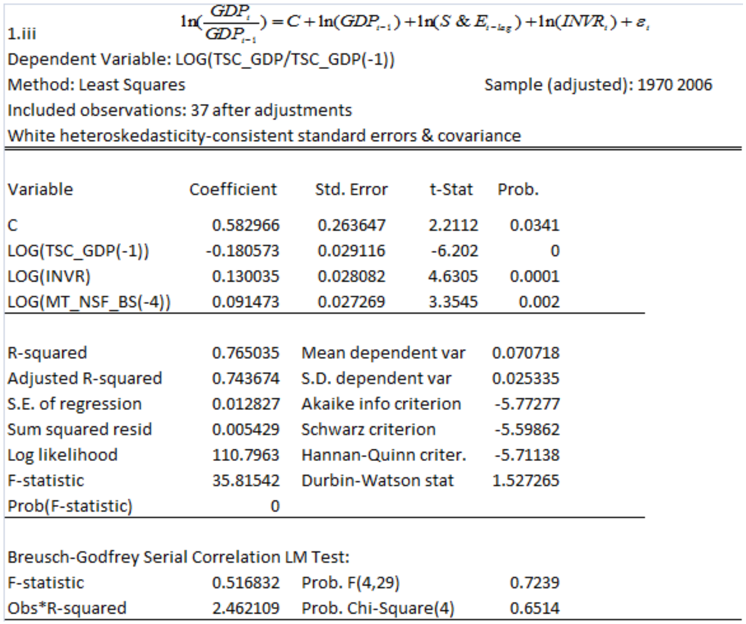
Dependent Variable: LOG(TSC_GDP/TSC_GDP(-1))
Method: Least Squares Sample (adjusted): 1970 2006
Included observations: 37 after adjustments
White heteroskedasticity-consistent standard errors & covariance

Variable	Coefficient	Std. Error	t-Stat	Prob.
C	-0.578882	3.031177	-0.191	0.8497
LOG(TSC_GDP(-1))	-0.051276	0.026451	-1.939	0.0612
LOG(MT_NSF_BS(-4))	0.136957	0.026779	5.1143	0
TimeTrend	0.000202	0.001883	0.1074	0.9151

R-squared	0.612534	Mean dependent var	0.070718
Adjusted R-squared	0.57731	S.D. dependent var	0.025335
S.E. of regression	0.016471	Akaike info criterion	-5.27258
Sum squared resid	0.008953	Schwarz criterion	-5.09843
Log likelihood	101.5428	Hannan-Quinn criter.	-5.21119
F-statistic	17.38958	Durbin-Watson stat	1.921727
Prob(F-statistic)	0.000001		

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.790439	Prob. F(8,25)	0.6158
Obs*R-squared	7.46947	Prob. Chi-Square(8)	0.4869



1.iii $\ln(\frac{GDP_t}{GDP_{t-1}}) = C + \ln(GDP_{t-1}) + \ln(S \& E_{t-lag}) + \ln(INVR_t) + \varepsilon_t$

Dependent Variable: LOG(TSC_GDP/TSC_GDP(-1))

Method: Least Squares Sample (adjusted): 1970 2006

Included observations: 37 after adjustments

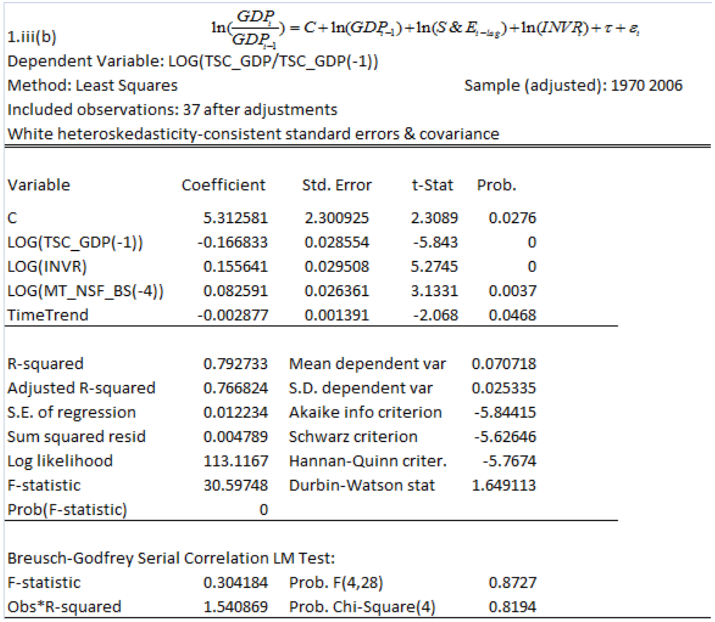
White heteroskedasticity-consistent standard errors & covariance

Variable	Coefficient	Std. Error	t-Stat	Prob.
C	0.582966	0.263647	2.2112	0.0341
LOG(TSC_GDP(-1))	-0.180573	0.029116	-6.202	0
LOG(INVR)	0.130035	0.028082	4.6305	0.0001
LOG(MT_NSF_BS(-4))	0.091473	0.027269	3.3545	0.002

R-squared	0.765035	Mean dependent var	0.070718
Adjusted R-squared	0.743674	S.D. dependent var	0.025335
S.E. of regression	0.012827	Akaike info criterion	-5.77277
Sum squared resid	0.005429	Schwarz criterion	-5.59862
Log likelihood	110.7963	Hannan-Quinn criter.	-5.71138
F-statistic	35.81542	Durbin-Watson stat	1.527265
Prob(F-statistic)	0		

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.516832	Prob. F(4,29)	0.7239
Obs*R-squared	2.462109	Prob. Chi-Square(4)	0.6514



1.iii(b) $\ln(\frac{GDP_t}{GDP_{t-1}}) = C + \ln(GDP_{t-1}) + \ln(S \& E_{t-lag}) + \ln(INVR_t) + \tau + \varepsilon_t$

Dependent Variable: LOG(TSC_GDP/TSC_GDP(-1))

Method: Least Squares Sample (adjusted): 1970 2006

Included observations: 37 after adjustments

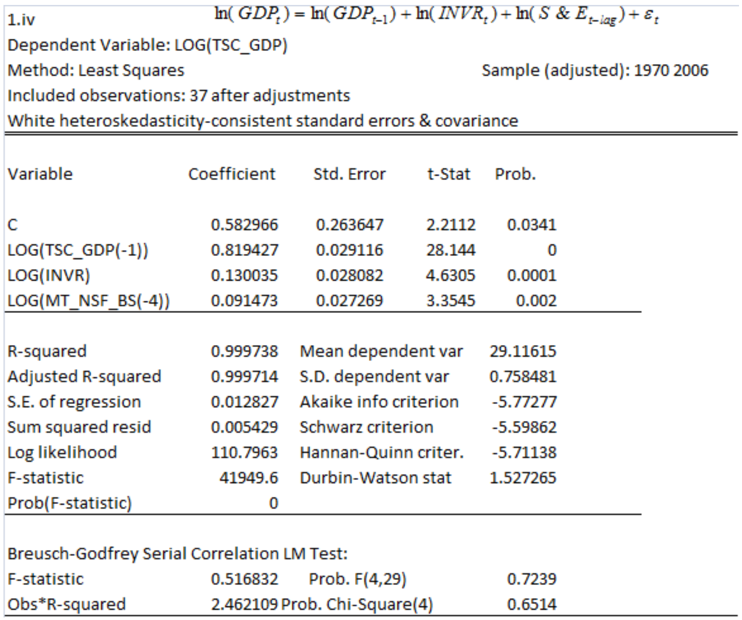
White heteroskedasticity-consistent standard errors & covariance

Variable	Coefficient	Std. Error	t-Stat	Prob.
C	5.312581	2.300925	2.3089	0.0276
LOG(TSC_GDP(-1))	-0.166833	0.028554	-5.843	0
LOG(INVR)	0.155641	0.029508	5.2745	0
LOG(MT_NSF_BS(-4))	0.082591	0.026361	3.1331	0.0037
TimeTrend	-0.002877	0.001391	-2.068	0.0468

R-squared	0.792733	Mean dependent var	0.070718
Adjusted R-squared	0.766824	S.D. dependent var	0.025335
S.E. of regression	0.012234	Akaike info criterion	-5.84415
Sum squared resid	0.004789	Schwarz criterion	-5.62646
Log likelihood	113.1167	Hannan-Quinn criter.	-5.7674
F-statistic	30.59748	Durbin-Watson stat	1.649113
Prob(F-statistic)	0		

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.304184	Prob. F(4,28)	0.8727
Obs*R-squared	1.540869	Prob. Chi-Square(4)	0.8194



1.iv $\ln(GDP_t) = \ln(GDP_{t-1}) + \ln(INVR_t) + \ln(S \& E_{t-lag}) + \varepsilon_t$

Dependent Variable: LOG(TSC_GDP)

Method: Least Squares Sample (adjusted): 1970 2006

Included observations: 37 after adjustments

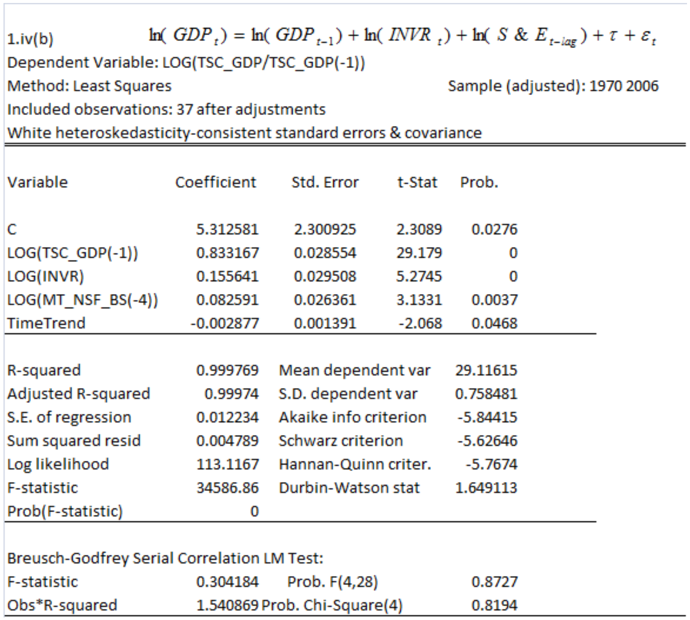
White heteroskedasticity-consistent standard errors & covariance

Variable	Coefficient	Std. Error	t-Stat	Prob.
C	0.582966	0.263647	2.2112	0.0341
LOG(TSC_GDP(-1))	0.819427	0.029116	28.144	0
LOG(INVR)	0.130035	0.028082	4.6305	0.0001
LOG(MT_NSF_BS(-4))	0.091473	0.027269	3.3545	0.002

R-squared	0.999738	Mean dependent var	29.11615
Adjusted R-squared	0.999714	S.D. dependent var	0.758481
S.E. of regression	0.012827	Akaike info criterion	-5.77277
Sum squared resid	0.005429	Schwarz criterion	-5.59862
Log likelihood	110.7963	Hannan-Quinn criter.	-5.71138
F-statistic	41949.6	Durbin-Watson stat	1.527265
Prob(F-statistic)	0		

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.516832	Prob. F(4,29)	0.7239
Obs*R-squared	2.462109	Prob. Chi-Square(4)	0.6514



1.iv(b) $\ln(GDP_t) = \ln(GDP_{t-1}) + \ln(INVR_t) + \ln(S \& E_{t-lag}) + \tau + \varepsilon_t$

Dependent Variable: LOG(TSC_GDP/TSC_GDP(-1))

Method: Least Squares Sample (adjusted): 1970 2006

Included observations: 37 after adjustments

White heteroskedasticity-consistent standard errors & covariance

Variable	Coefficient	Std. Error	t-Stat	Prob.
C	5.312581	2.300925	2.3089	0.0276
LOG(TSC_GDP(-1))	0.833167	0.028554	29.179	0
LOG(INVR)	0.155641	0.029508	5.2745	0
LOG(MT_NSF_BS(-4))	0.082591	0.026361	3.1331	0.0037
TimeTrend	-0.002877	0.001391	-2.068	0.0468

R-squared	0.999769	Mean dependent var	29.11615
Adjusted R-squared	0.99974	S.D. dependent var	0.758481
S.E. of regression	0.012234	Akaike info criterion	-5.84415
Sum squared resid	0.004789	Schwarz criterion	-5.62646
Log likelihood	113.1167	Hannan-Quinn criter.	-5.7674
F-statistic	34586.86	Durbin-Watson stat	1.649113
Prob(F-statistic)	0		

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.304184	Prob. F(4,28)	0.8727
Obs*R-squared	1.540869	Prob. Chi-Square(4)	0.8194

Appendix B: Regression Results for model 2 variants at 4 years of lag

2.i $\ln(\frac{GDP_t}{GDP_{t-1}}) = C + \ln(\frac{CAP_t}{CAP_{t-1}}) + \ln(\frac{UNEM_t}{UNEM_{t-1}}) + \ln(GRAD_{t-lag}) + \ln(S\,\&\,E_{t-lag}) + \varepsilon_t$

Dependent Variable: LOG(TSC_GDP/TSC_GDP(-1))
Method: Least Squares Sample (adjusted): 1981 2006
Included observations: 26 after adjustments
White heteroskedasticity-consistent standard errors & covariance

Variable	Coef.	Std. Error	t-Stat	Prob.
C	1.158689	0.447066	2.591761	0.017
LOG(KT_CAPR/KT_CAPR(-1))	0.168877	0.066435	2.541991	0.019
LOG(UNEM/UNEM(-1))	-0.059648	0.029551	-2.018465	0.0565
LOG(ET_NSF_BS(-4))	-0.333666	0.070752	-4.716011	0.0001
LOG(MT_NSF_BS(-4))	0.276612	0.076307	3.625009	0.0016

R-squared	0.547718	Mean dependent var	0.060463
Adjusted R-squared	0.461569	S.D. dependent var	0.019866
S.E. of regression	0.014577	Akaike info criterion	-5.447706
Sum squared resid	0.004462	Schwarz criterion	-5.205765
Log likelihood	75.82018	Hannan-Quinn criter.	-5.378036
F-statistic	6.357795	Durbin-Watson stat	0.912437
Prob(F-statistic)	0.001626		

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.485423	Prob. F(4,17)	0.7463
Obs*R-squared	2.66523	ob. Chi-Square(4)	0.6153

2.i(b) $\ln(\frac{GDP_t}{GDP_{t-1}}) = C + \ln(\frac{CAP_t}{CAP_{t-1}}) + \ln(\frac{UNEM_t}{UNEM_{t-1}}) + \ln(GRAD_{t-lag}) + \ln(S\,\&\,E_{t-lag}) + \tau + \varepsilon_t$

Dependent Variable: LOG(TSC_GDP/TSC_GDP(-1))
Method: Least Squares Sample (adjusted): 1981 2006
Included observations: 26 after adjustments
White heteroskedasticity-consistent standard errors & covariance

Variable	Coef.	Std. Error	t-Stat	Prob.
C	5.471734	3.298981	1.658613	0.1128
LOG(KT_CAPR/KT_CAPR(-1))	0.170943	0.076448	2.236058	0.0369
LOG(UNEM/UNEM(-1))	-0.053755	0.033448	-1.607101	0.1237
LOG(ET_NSF_BS(-4))	-0.115494	0.151597	-0.76185	0.455
LOG(MT_NSF_BS(-4))	0.338571	0.075674	4.474085	0.0002
TimeTrend	-0.00408	0.002844	-1.434345	0.1669

R-squared	0.63175	Mean dependent var	0.060463
Adjusted R-squared	0.539687	S.D. dependent var	0.019866
S.E. of regression	0.013478	Akaike info criterion	-5.576326
Sum squared resid	0.003633	Schwarz criterion	-5.285996
Log likelihood	78.49224	Hannan-Quinn criter.	-5.492722
F-statistic	6.862173	Durbin-Watson stat	1.181361
Prob(F-statistic)	0.000706		

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.463241	Prob. F(4,16)	0.7617
Obs*R-squared	2.698545	Prob. Chi-Square(4)	0.6095

2.i(c) $\ln(\frac{GDP_t}{GDP_{t-1}}) = C + \ln(GDP_{t-1}) + \ln(\frac{CAP_t}{CAP_{t-1}}) + \ln(\frac{UNEM_t}{UNEM_{t-1}}) + \ln(GRAD_{t-lag}) + \ln(S\,\&\,E_{t-lag}) + \varepsilon_t$

Dependent Variable: LOG(TSC_GDP/TSC_GDP(-1))
Method: Least Squares Sample (adjusted): 1981 2006
Included observations: 26 after adjustments
White heteroskedasticity-consistent standard errors & covariance

Variable	Coefficient	Std. Error	t-Stat	Prob.
C	-0.730938	0.741357	-0.985946	0.3359
LOG(TSC_GDP(-1))	-0.07876	0.036281	-2.170862	0.0422
LOG(KT_CAPR/KT_CAPR(-1))	0.156757	0.077912	2.011985	0.0579
LOG(UNEM/UNEM(-1))	-0.058474	0.031709	-1.844088	0.08
LOG(ET_NSF_BS(-4))	-0.089399	0.120427	-0.742348	0.4665
LOG(MT_NSF_BS(-4))	0.340821	0.069142	4.929272	0.0001

R-squared	0.72364	Mean dependent var	0.060463
Adjusted R-squared	0.654549	S.D. dependent var	0.019866
S.E. of regression	0.011676	Akaike info criterion	-5.863384
Sum squared resid	0.002727	Schwarz criterion	-5.573054
Log likelihood	82.22399	Hannan-Quinn criter.	-5.779779
F-statistic	10.47385	Durbin-Watson stat	1.388998
Prob(F-statistic)	0.000048		

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.307422	Prob. F(4,16)	0.8688
Obs*R-squared	1.855628	Prob. Chi-Square(4)	0.7623

2.i(d) $\ln(\frac{GDP_t}{GDP_{t-1}}) = C + \ln(GDP_{t-1}) + \ln(\frac{CAP_t}{CAP_{t-1}}) + \ln(\frac{UNEM_t}{UNEM_{t-1}}) + \ln(GRAD_{t-lag}) + \ln(S\,\&\,E_{t-lag}) + \tau + \varepsilon_t$

Dependent Variable: LOG(TSC_GDP/TSC_GDP(-1))
Method: Least Squares Sample (adjusted): 1981 2006
Included observations: 26 after adjustments
White heteroskedasticity-consistent standard errors & covariance

Variable	Coefficient	Std. Error	t-Stat	Prob.
C	-21.06024	6.836821	-3.080414	0.0062
LOG(TSC_GDP(-1))	-0.267729	0.078107	-3.427728	0.0028
LOG(KT_CAPR/KT_CAPR(-1))	0.120113	0.061327	1.958587	0.065
LOG(UNEM/UNEM(-1))	-0.077239	0.023005	-3.357489	0.0033
LOG(ET_NSF_BS(-4))	-0.302334	0.114369	-2.643494	0.016
LOG(MT_NSF_BS(-4))	0.267965	0.068547	3.909215	0.0009
TimeTrend	0.014941	0.004821	3.099116	0.0059

R-squared	0.83798	Mean dependent var	0.060463
Adjusted R-squared	0.786816	S.D. dependent var	0.019866
S.E. of regression	0.009172	Akaike info criterion	-6.320448
Sum squared resid	0.001598	Schwarz criterion	-5.98173
Log likelihood	89.16582	Hannan-Quinn criter.	-6.222909
F-statistic	16.37827	Durbin-Watson stat	1.588339
Prob(F-statistic)	0.000001		

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.123716	Prob. F(4,15)	0.9717
Obs*R-squared	0.830367	Prob. Chi-Square(4)	0.9343

2.ii

$$\ln\left(\frac{GDP_i}{GDP_{i-1}}\right) = C + \ln(GDP_{i-1}) + \ln\left(\frac{CAP_i}{CAP_{i-1}}\right) + \ln\left(\frac{UNEM_i}{UNEM_{i-1}}\right) + \ln(OTHGR_{lag}) + \ln(S\&E_{i-lag}) + \varepsilon_i$$

Dependent Variable: LOG(TSC_GDP/TSC_GDP(-1))
Method: Least Squares　Sample (adjusted): 1981 2006
Included observations: 26 after adjustments
White heteroskedasticity-consistent standard errors & covariance

Variable	Coefficient	Std. Error	t-Stat	Prob.
C	-0.788578	0.680546	-1.158743	0.2602
LOG(TSC_GDP(-1))	-0.078817	0.036225	-2.175768	0.0417
LOG(KT_CAPR/KT_CAPR(-1))	0.156789	0.077984	2.010527	0.0581
LOG(UNEM/UNEM(-1))	-0.058452	0.031716	-1.84299	0.0802
LOG(OTHBS(-4))	-0.060568	0.081783	-0.740599	0.4675
LOG(MT_NSF_BS(-4))	0.312232	0.074339	4.20013	0.0004

R-squared	0.723598	Mean dependent var	0.060463
Adjusted R-squared	0.654498	S.D. dependent var	0.019866
S.E. of regression	0.011677	Akaike info criterion	-5.863235
Sum squared resid	0.002727	Schwarz criterion	-5.572905
Log likelihood	82.22205	Hannan-Quinn criter.	-5.77963
F-statistic	10.4717	Durbin-Watson stat	1.389026
Prob(F-statistic)	0.000048		

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.307859	Prob. F(4,16)	0.8685
Obs*R-squared	1.858075	Prob. Chi-Square(4)	0.7618

2.ii(b)

$$\ln\left(\frac{GDP_i}{GDP_{i-1}}\right) = C + \ln(GDP_{i-1}) + \ln\left(\frac{CAP_i}{CAP_{i-1}}\right) + \ln\left(\frac{UNEM_i}{UNEM_{i-1}}\right) + \ln(OTHGR_{i-lag}) + \ln(S\&E_{i-lag}) + \tau + \varepsilon_i$$

Dependent Variable: LOG(TSC_GDP/TSC_GDP(-1))
Method: Least Squares　Sample (adjusted): 1981 2006
Included observations: 26 after adjustments
White heteroskedasticity-consistent standard errors & covariance

Variable	Coefficient	Std. Error	t-Stat	Prob.
C	-21.36233	6.860509	-3.113811	0.0057
LOG(TSC_GDP(-1))	-0.268748	0.078062	-3.442775	0.0027
LOG(KT_CAPR/KT_CAPR(-1))	0.120536	0.061189	1.969886	0.0636
LOG(UNEM/UNEM(-1))	-0.077255	0.022946	-3.366801	0.0032
LOG(ET_NSF_BS(-4))	-0.207248	0.077948	-2.658798	0.0155
LOG(MT_NSF_BS(-4))	0.171443	0.059865	2.863824	0.0099
TimeTrend	0.015023	0.004826	3.11257	0.0057

R-squared	0.838628	Mean dependent var	0.060463
Adjusted R-squared	0.787668	S.D. dependent var	0.019866
S.E. of regression	0.009154	Akaike info criterion	-6.324453
Sum squared resid	0.001592	Schwarz criterion	-5.985735
Log likelihood	89.21789	Hannan-Quinn criter.	-6.226915
F-statistic	16.45671	Durbin-Watson stat	1.588352
Prob(F-statistic)	0.000001		

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.123716	Prob. F(4,15)	0.9717
Obs*R-squared	0.830367	Prob. Chi-Square(4)	0.9343

2.iii

$$\ln\left(\frac{GDP_i}{GDP_{i-1}}\right) = C + \ln(GDP_{i-1}) + \ln\left(\frac{INVR_i}{INVR_{i-1}}\right) + \ln\left(\frac{UNEM_i}{UNEM_{i-1}}\right) + \ln(OTHGR_{i-lag}) + \ln(S\&E_{i-lag}) + \varepsilon_i$$

Dependent Variable: LOG(TSC_GDP/TSC_GDP(-1))
Method: Least Squares　Sample (adjusted): 1981 2006
Included observations: 26 after adjustments
White heteroskedasticity-consistent standard errors & covariance

Variable	Coefficient	Std. Error	t-Stat	Prob.
C	-0.567232	0.306426	-1.85112	0.079
LOG(TSC_GDP(-1))	-0.059792	0.013508	-4.426421	0.0003
LOG(INVR/INVR(-1))	0.203092	0.046933	4.327274	0.0003
LOG(UNEM/UNEM(-1))	-0.012858	0.026891	-0.478145	0.6377
LOG(OTHBS(-4))	-0.043571	0.040296	-1.081281	0.2924
LOG(MT_NSF_BS(-4))	0.232364	0.040719	5.706489	0

R-squared	0.875817	Mean dependent var	0.060463
Adjusted R-squared	0.844771	S.D. dependent var	0.019866
S.E. of regression	0.007827	Akaike info criterion	-6.663331
Sum squared resid	0.001225	Schwarz criterion	-6.373001
Log likelihood	92.6233	Hannan-Quinn criter.	-6.579726
F-statistic	28.21044	Durbin-Watson stat	1.887127
Prob(F-statistic)	0		

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.108708	Prob. F(4,16)	0.9777
Obs*R-squared	0.687908	Prob. Chi-Square(4)	0.9528

2.iii(b)

$$\ln\left(\frac{GDP_i}{GDP_{i-1}}\right) = C + \ln(GDP_{i-1}) + \ln\left(\frac{INVR_i}{INVR_{i-1}}\right) + \ln\left(\frac{UNEM_i}{UNEM_{i-1}}\right) + \ln(OTHGR_{i-lag}) + \ln(S\&E_{i-lag}) + \tau + \varepsilon_i$$

Dependent Variable: LOG(TSC_GDP/TSC_GDP(-1))
Method: Least Squares　Sample (adjusted): 1981 2006
Included observations: 26 after adjustments
White heteroskedasticity-consistent standard errors & covariance

Variable	Coefficient	Std. Error	t-Stat	Prob.
C	-11.25955	5.269248	-2.136842	0.0458
LOG(TSC_GDP(-1))	-0.162315	0.05214	-3.113084	0.0057
LOG(INVR/INVR(-1))	0.158649	0.049981	3.17416	0.005
LOG(UNEM/UNEM(-1))	-0.037282	0.028532	-1.306675	0.2069
LOG(OTHBS(-4))	-0.118221	0.059129	-1.999378	0.0601
LOG(MT_NSF_BS(-4))	0.172571	0.046549	3.707268	0.0015
TimeTrend	0.007768	0.003774	2.058211	0.0536

R-squared	0.897905	Mean dependent var	0.060463
Adjusted R-squared	0.865665	S.D. dependent var	0.019866
S.E. of regression	0.007281	Akaike info criterion	-6.782266
Sum squared resid	0.001007	Schwarz criterion	-6.443548
Log likelihood	95.16946	Hannan-Quinn criter.	-6.684728
F-statistic	27.85031	Durbin-Watson stat	1.968378
Prob(F-statistic)	0		

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.362717	Prob. F(4,15)	0.8313
Obs*R-squared	2.293045	Prob. Chi-Square(4)	0.682

Appendix C: Panel Data Results for Models 1 and 2 variants across range of Lags

Model P1.i:

$$\log(GDP_{i,t}) = C + \log(GDP_{i,t-1}) + \log(S\&E_{i,t-lag}) + a_i + \varepsilon_t$$

S&E Lag	GDP	Constant	GDP-1	S&E	Note
0	Value	5.614201***	0.491113***	-0.033151**	White heteroskedasticity-consistent standard errors & covariance
1	Value	3.145283	0.69028***	0.006724***	White heteroskedasticity-consistent standard errors & covariance
2	Value	0.963907	0.850512***	0.056529***	White heteroskedasticity-consistent standard errors & covariance
3	Value	0.852174	0.847743***	0.070089***	White heteroskedasticity-consistent standard errors & covariance
4	Value	1.169166	0.82871***	0.058659***	White heteroskedasticity-consistent standard errors & covariance
5	Value	1.611672	0.831961***	0.013671	White heteroskedasticity-consistent standard errors & covariance
6	Value	2.636072**	0.737471***	0.008525	White heteroskedasticity-consistent standard errors & covariance
7	Value	3.145283**	0.69028***	0.006724	White heteroskedasticity-consistent standard errors & covariance
8	Value	5.614201***	0.491113***	-0.033151**	White heteroskedasticity-consistent standard errors & covariance

where *, **, and *** are significant at 10%, 5%, and 1%, respectively.

Model P1.ii:

$$\log(GDP_{i,t}) = C + \log(GDP_{i,t-1}) + \log(S\&E_{i,t-lag}) + a_i + \tau + \varepsilon_t$$

S&E Lag	GDP	Constant	GDP-1	S&E	τ	Note
0	Value	-19.07257***	0.801381***	0.009811	0.010492***	White heteroskedasticity-consistent standard errors & covariance
1	Value	-8.536902	0.799427***	0.039714***	0.005084	White heteroskedasticity-consistent standard errors & covariance
2	Value	-6.808442	0.78377***	0.049815***	0.004249	White heteroskedasticity-consistent standard errors & covariance
3	Value	-6.356896	0.786341***	0.064427***	0.003935	White heteroskedasticity-consistent standard errors & covariance
4	Value	-5.569823	0.774806***	0.053453**	0.00366	White heteroskedasticity-consistent standard errors & covariance
5	Value	-9.632344	0.744671***	0.007783	0.006079	White heteroskedasticity-consistent standard errors & covariance
6	Value	10.51838	0.795983***	0.012586	-0.004247	White heteroskedasticity-consistent standard errors & covariance
7	Value	14.13611	0.772513***	0.010955	-0.005918	White heteroskedasticity-consistent standard errors & covariance
8	Value	50.35969	0.832587***	-0.020377	-0.024104	White heteroskedasticity-consistent standard errors & covariance

where *, **, and *** are significant at 10%, 5%, and 1%, respectively.

Model P1C.ii: $\log(GDP_{i,t}) = C + \log(GDP_{i,t-1}) + \log(S \& E_{i,t-lag}) + a_i + \varepsilon_t$

S&E Lag	GDP	Constant	GDP-1	S&E	τ	Note
0	Value	-0.74827	0.910616***	0.015811	0.001479	White heteroskedasticity-consistent standard errors & covariance
1	Value	7.994583	0.91876***	0.028401***	-0.003059	White heteroskedasticity-consistent standard errors & covariance
2	Value	10.43292*	0.928785***	0.037136***	-0.004452	White heteroskedasticity-consistent standard errors & covariance
3	Value	11.03099	0.901579***	0.050961***	-0.004464	White heteroskedasticity-consistent standard errors & covariance
4	Value	14.27231	0.905145***	0.038196***	-0.006058	White heteroskedasticity-consistent standard errors & covariance
5	Value	18.58184*	0.932488***	0.020752***	-0.008473*	White heteroskedasticity-consistent standard errors & covariance
6	Value	28.32962***	0.961928***	0.007919	-0.013649***	White heteroskedasticity-consistent standard errors & covariance
7	Value	33.68453**	0.925696***	-0.005164	-0.01577**	White heteroskedasticity-consistent standard errors & covariance
8	Value	50.17787***	0.947461***	-0.024831	-0.024168***	White heteroskedasticity-consistent standard errors & covariance

where *, **, and *** are significant at 10%, 5%, and 1%, respectively.

Model P1.iii:

$$\ln(\frac{GDP_{i,t}}{GDP_{i,t}}) = \ln(GDP_{i,t-1}) + \ln(INVR_{i,t}) + \ln(S \& E_{i,t-lag}) + \tau + a_i + \varepsilon_t$$

S&E Lag	GDP	Constant	GDP-1	S&E	τ	INVR	Note
0	Growth	-6.316883**	-0.344117***	0.035684***	0.003833***	0.206181***	White heteroskedasticity-consistent standard errors & covariance
1	Growth	-7.057466**	-0.369742***	0.033162**	0.004332***	0.209347***	White heteroskedasticity-consistent standard errors & covariance
2	Growth	-5.766001*	-0.369228***	0.029615*	0.003677**	0.215457***	White heteroskedasticity-consistent standard errors & covariance
3	Growth	-6.770137*	-0.388836***	0.033349*	0.004272**	0.212538***	White heteroskedasticity-consistent standard errors & covariance
4	Growth	-11.78556**	-0.42835***	0.010128	0.007051***	0.221523***	White heteroskedasticity-consistent standard errors & covariance
5	Growth	-7.29373	-0.391908***	-0.005747	0.004784	0.204057***	White heteroskedasticity-consistent standard errors & covariance
6	Growth	-6.893988	-0.455116***	0.037137**	0.004691	0.204298***	White heteroskedasticity-consistent standard errors & covariance
7	Growth	-3.191524	-0.518578***	0.051792***	0.003193	0.183242***	White heteroskedasticity-consistent standard errors & covariance
8	Growth	3.741245	-0.537174***	0.038293***	-0.0001	0.18466***	White heteroskedasticity-consistent standard errors & covariance

where *, **, and *** are significant at 10%, 5%, and 1%, respectively.

Model P1.iv: $$\ln(\frac{GDP_{i,t}}{GDP_{i,t}}) = \ln(GDP_{i,t-1}) + \ln(INVR_{i,t}) + \ln(S\,\&\,E_{i,t-lag}) + \log(pop_{i,t}) + \tau + a_i + \varepsilon_t$$

S&E Lag	GDP	Constant	GDP-1	S&E	τ	INVR	POP
0	Growth	-6.733265***	-0.353267***	0.028802***	0.005862***	0.207494***	-0.210638***
1	Growth	-7.664918***	-0.381118***	0.027909**	0.006465***	0.211603***	-0.211842*
2	Growth	-6.460696**	-0.381375***	0.025634*	0.006156***	0.216833***	-0.247827*
3	Growth	-7.219262*	-0.401931***	0.03378**	0.006737***	0.212922***	-0.262267**
4	Growth	-11.96427***	-0.440342***	0.013778	0.009158***	0.220988***	-0.237497
5	Growth	-7.324363	-0.398139***	-0.002399	0.005675	0.203659***	-0.103407
6	Growth	-6.79684	-0.445755***	0.031616	0.003491	0.204731***	0.135768
7	Growth	-3.093001	-0.503473***	0.042438**	0.001288	0.183595***	0.219055
8	Growth	3.739592	-0.534811***	0.036707	-0.000474	0.184387***	0.044627

where *, **, and *** are significant at 10%, 5%, and 1%, respectively.

Model P2.i:

$$\ln\left(\frac{GDP_t}{GDP_{t-1}}\right) = C + \ln(GDP_{t-1}) + \ln\left(\frac{CAP_t}{CAP_{t-1}}\right) + \ln\left(\frac{UNEM_t}{UNEM_{t-1}}\right) + \ln(OTHGR_{t-lag}) + \ln(S\&E_{t-lag}) + \varepsilon_t$$

S&E Lag	GDP	Constant	GDP-1	CAP	UNEM	GRADS	S&E	Note
0	Growth	0.091651	-0.029159***	0.126691***	-0.081233	0.006471	0.017084	White heteroskedasticity-consistent
1	Growth	0.240475	-0.058172**	0.118215***	-0.089433***	0.016665	0.019997*	White heteroskedasticity-consistent
2	Growth	0.227721	-0.076099**	0.119909***	-0.088825***	0.031565**	0.022541**	White heteroskedasticity-consistent
3	Growth	0.377219	-0.124924***	0.092843***	-0.104465***	0.058379**	0.026849	White heteroskedasticity-consistent
4	Growth	0.403046	-0.141262***	0.112989***	-0.10129***	0.074654***	0.022831	White heteroskedasticity-consistent
5	Growth	0.832151**	-0.165802***	0.100099***	-0.101354***	0.073653***	0.006896	White heteroskedasticity-consistent
6	Growth	1.192836	-0.219691***	0.089515***	-0.106438***	0.032625*	0.072085***	White heteroskedasticity-consistent
7	Growth	2.351949**	-0.287435***	0.100557***	-0.088449***	0.031823	0.02782	White heteroskedasticity-consistent
8	Growth	3.910123***	-0.458562***	0.210435***	-0.018441***	0.095728***	-0.022784	White heteroskedasticity-consistent

where *, **, and *** are significant at 10%, 5%, and 1%, respectively.

Model P2.ii: $$\ln\left(\frac{GDP_t}{GDP_{t-1}}\right) = C + \ln(GDP_{t-1}) + \ln\left(\frac{INVR_t}{INVR_{t-1}}\right) + \ln\left(\frac{UNEM_t}{UNEM_{t-1}}\right) + \ln(OTHGR_{t-lag}) + \ln(S\,\&\,E_{t-lag}) + \tau + \varepsilon_t$$

S&E Lag	GDP	Constant	GDP-1	INVR	UNEM	OTH-GRAD	S&E	τ
0	Growth	-3.337962	-0.044158***	0.189415***	-0.049615***	0.006751	0.010696	0.001815
1	Growth	-3.933416	-0.069143***	0.185828***	-0.052519***	0.01359	0.01629*	0.002172
2	Growth	-0.681186	-0.060876*	0.190176***	-0.047721***	0.027623	0.021214**	0.000404
3	Growth	-1.315992	-0.096871**	0.193495***	-0.045732***	0.057206***	0.021272	0.000736
4	Growth	-11.10694***	-0.155925***	0.208412***	-0.04299***	0.048489***	0.012703	0.006009***
5	Growth	-6.420344	-0.14678***	0.189964***	-0.051672***	0.057581***	0.01113	0.003586
6	Growth	-8.924082*	-0.210635***	0.19982***	-0.047572***	0.048479*	0.05697**	0.004982*
7	Growth	-7.967657	-0.248642***	0.206149***	-0.036339*	0.038161**	0.052758***	0.004783
8	Growth	1.985834	-0.205558***	0.252911***	-0.010779	0.099072***	0.000543	-0.000472

Model P2.ii(b): $$\ln\left(\frac{GDP_t}{GDP_{t-1}}\right) = C + \ln(GDP_{t-1}) + \ln\left(\frac{CAP_t}{CAP_{t-1}}\right) + \ln\left(\frac{UNEM_t}{UNEM_{t-1}}\right) + \ln(OTHGR_{t-lag}) + \ln(S\,\&\,E_{t-lag}) + \tau + \varepsilon_t$$

S&E Lag	GDP	Constant	GDP-1	CAP	UNEM	OTH-GRAD	S&E	τ
0	Growth	-7.639438**	-0.089888***	0.126935***	-0.084832***	-0.002756	0.016597	0.004217**
1	Growth	-9.094619**	-0.125466***	0.116644***	-0.094697***	0.003173	0.018311	0.005081**
2	Growth	-5.255047	-0.113855**	0.118629***	-0.091085***	0.02195	0.021928*	0.002983
3	Growth	-3.675112	-0.151813**	0.094219***	-0.104439***	0.051873**	0.025873	0.002198
4	Growth	-15.78786***	-0.245407***	0.128277***	-0.099952***	0.056524***	0.01708	0.00873***
5	Growth	-10.33011*	-0.238305***	0.111838***	-0.101116***	0.068197***	0.0036	0.005979**
6	Growth	-12.6673	-0.311577***	0.105676***	-0.106656***	0.032799*	0.068153***	0.007393*
7	Growth	-9.328459	-0.363017***	0.11768**	-0.088933***	0.034741*	0.03081	0.006174
8	Growth	-7.61015	-0.53227***	0.224545***	-0.022973	0.099472***	-0.013635	0.006049

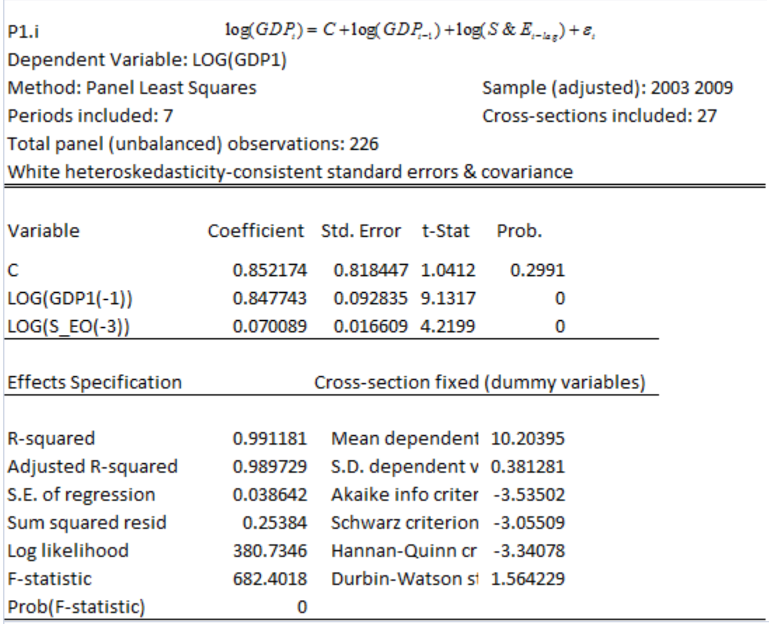
where *, **, and *** are significant at 10%, 5%, and 1%, respectively.

Model P2.iii: $$\ln\left(\frac{GDP_{i,t}}{GDP_{i,t-1}}\right) = C + \ln(GDP_{i,t-1}) + \ln\left(\frac{INVR_{i,t}}{INVR_{i,t-1}}\right) + \ln\left(\frac{LABOR_{i,t}}{LABOR_{i,t-1}}\right) + \ln\left(\frac{OTHR_{i,t}}{OTHR_{i,t}}\right) + \ln(S\&E_{i,t-lag}) + \varepsilon_t$$

S&E Lag	GDP	Constant	GDP-1	INVR	LABOR	OTH-GR	S&E	Note
0	Growth	0.002395	-0.022558*	0.231699***	0.040939	0.008198	0.016706*	White heteroskedasticity-consistent
1	Growth	0.064999	-0.045935***	0.23116***	0.115189	0.015653	0.025561***	White heteroskedasticity-consistent
2	Growth	0.091445	-0.060769*	0.229498***	0.190807	0.023955	0.028489***	White heteroskedasticity-consistent
3	Growth	-0.042062	-0.080059**	0.239993***	0.15335	0.059757***	0.021016	White heteroskedasticity-consistent
4	Growth	-0.074637	-0.070145***	0.251558***	0.14592	0.064049***	0.009806	White heteroskedasticity-consistent
5	Growth	0.094691	-0.075144**	0.243995***	0.132052	0.056276***	0.007298	White heteroskedasticity-consistent
6	Growth	0.383818	-0.1452***	0.243542***	0.098262	0.058312**	0.04786	White heteroskedasticity-consistent
7	Growth	1.039376	-0.198488***	0.237862***	0.007199	0.043888*	0.054123***	White heteroskedasticity-consistent
8	Growth	1.45617	-0.258607***	0.228706***	1.0576**	0.103285***	0.007434	White heteroskedasticity-consistent

where *, **, and *** are significant at 10%, 5%, and 1%, respectively.

Appendix D: Panel Data Results with Greater Statistical Detail



P1.i $\log(GDP_t) = C + \log(GDP_{t-1}) + \log(S\&E_{t-lag}) + \varepsilon_t$

Dependent Variable: LOG(GDP1)

Method: Panel Least Squares	Sample (adjusted): 2003 2009
Periods included: 7	Cross-sections included: 27

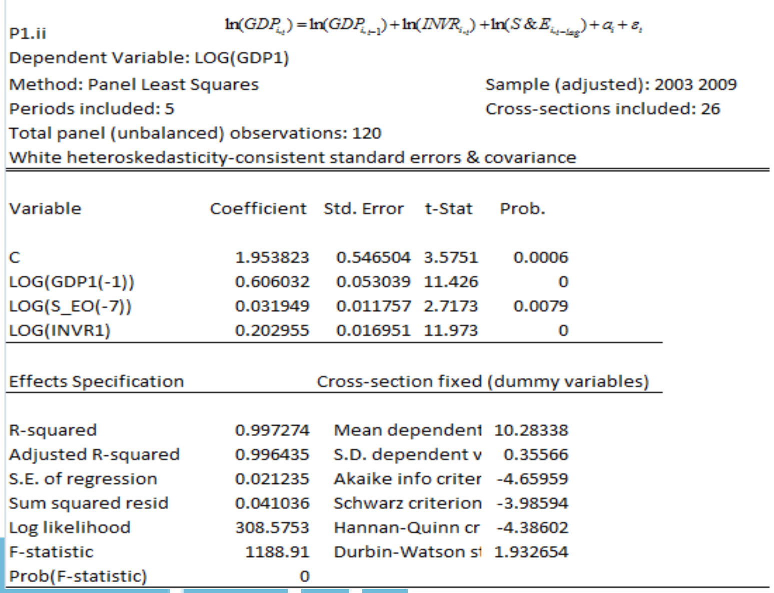
Total panel (unbalanced) observations: 226

White heteroskedasticity-consistent standard errors & covariance

Variable	Coefficient	Std. Error	t-Stat	Prob.
C	0.852174	0.818447	1.0412	0.2991
LOG(GDP1(-1))	0.847743	0.092835	9.1317	0
LOG(S_EO(-3))	0.070089	0.016609	4.2199	0

Effects Specification Cross-section fixed (dummy variables)

R-squared	0.991181	Mean dependent	10.20395
Adjusted R-squared	0.989729	S.D. dependent v	0.381281
S.E. of regression	0.038642	Akaike info criter	-3.53502
Sum squared resid	0.25384	Schwarz criterion	-3.05509
Log likelihood	380.7346	Hannan-Quinn cr	-3.34078
F-statistic	682.4018	Durbin-Watson st	1.564229
Prob(F-statistic)	0		



P1.ii $\ln(GDP_{i,t}) = \ln(GDP_{i,t-1}) + \ln(INVR_{i,t}) + \ln(S\&E_{i,t-lag}) + a_i + \varepsilon_t$

Dependent Variable: LOG(GDP1)

Method: Panel Least Squares	Sample (adjusted): 2003 2009
Periods included: 5	Cross-sections included: 26

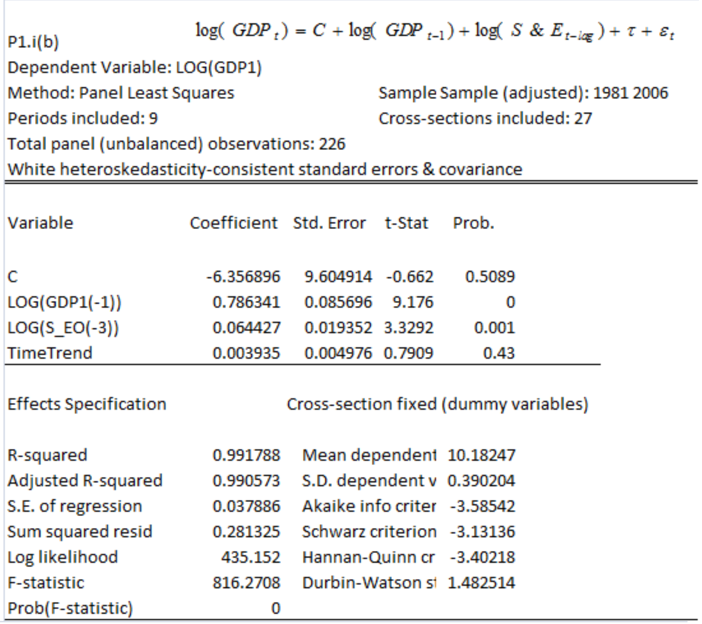
Total panel (unbalanced) observations: 120

White heteroskedasticity-consistent standard errors & covariance

Variable	Coefficient	Std. Error	t-Stat	Prob.
C	1.953823	0.546504	3.5751	0.0006
LOG(GDP1(-1))	0.606032	0.053039	11.426	0
LOG(S_EO(-7))	0.031949	0.011757	2.7173	0.0079
LOG(INVR1)	0.202955	0.016951	11.973	0

Effects Specification Cross-section fixed (dummy variables)

R-squared	0.997274	Mean dependent	10.28338
Adjusted R-squared	0.996435	S.D. dependent v	0.35566
S.E. of regression	0.021235	Akaike info criter	-4.65959
Sum squared resid	0.041036	Schwarz criterion	-3.98594
Log likelihood	308.5753	Hannan-Quinn cr	-4.38602
F-statistic	1188.91	Durbin-Watson st	1.932654
Prob(F-statistic)	0		



P1.i(b) $\log(GDP_t) = C + \log(GDP_{t-1}) + \log(S\&E_{t-lag}) + \tau + \varepsilon_t$

Dependent Variable: LOG(GDP1)

Method: Panel Least Squares	Sample Sample (adjusted): 1981 2006
Periods included: 9	Cross-sections included: 27

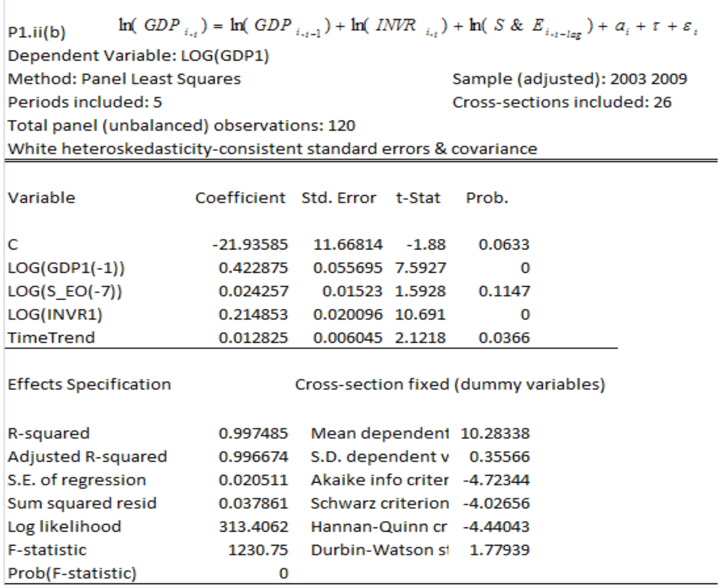
Total panel (unbalanced) observations: 226

White heteroskedasticity-consistent standard errors & covariance

Variable	Coefficient	Std. Error	t-Stat	Prob.
C	-6.356896	9.604914	-0.662	0.5089
LOG(GDP1(-1))	0.786341	0.085696	9.176	0
LOG(S_EO(-3))	0.064427	0.019352	3.3292	0.001
TimeTrend	0.003935	0.004976	0.7909	0.43

Effects Specification Cross-section fixed (dummy variables)

R-squared	0.991788	Mean dependent	10.18247
Adjusted R-squared	0.990573	S.D. dependent v	0.390204
S.E. of regression	0.037886	Akaike info criter	-3.58542
Sum squared resid	0.281325	Schwarz criterion	-3.13136
Log likelihood	435.152	Hannan-Quinn cr	-3.40218
F-statistic	816.2708	Durbin-Watson st	1.482514
Prob(F-statistic)	0		



P1.ii(b) $\ln(GDP_{i,t}) = \ln(GDP_{i,t-1}) + \ln(INVR_{i,t}) + \ln(S\&E_{i,t-lag}) + a_i + \tau + \varepsilon_t$

Dependent Variable: LOG(GDP1)

Method: Panel Least Squares	Sample (adjusted): 2003 2009
Periods included: 5	Cross-sections included: 26

Total panel (unbalanced) observations: 120

White heteroskedasticity-consistent standard errors & covariance

Variable	Coefficient	Std. Error	t-Stat	Prob.
C	-21.93585	11.66814	-1.88	0.0633
LOG(GDP1(-1))	0.422875	0.055695	7.5927	0
LOG(S_EO(-7))	0.024257	0.01523	1.5928	0.1147
LOG(INVR1)	0.214853	0.020096	10.691	0
TimeTrend	0.012825	0.006045	2.1218	0.0366

Effects Specification Cross-section fixed (dummy variables)

R-squared	0.997485	Mean dependent	10.28338
Adjusted R-squared	0.996674	S.D. dependent v	0.35566
S.E. of regression	0.020511	Akaike info criter	-4.72344
Sum squared resid	0.037861	Schwarz criterion	-4.02656
Log likelihood	313.4062	Hannan-Quinn cr	-4.44043
F-statistic	1230.75	Durbin-Watson st	1.77939
Prob(F-statistic)	0		

$$\ln(\frac{GDP_{i,t}}{GDP_{i,}})=\ln(GDP_{i,t-1})+\ln(INVR_{i,t})+\ln(S\,\&\,E_{i,t-lag})+\tau+a_i+\varepsilon_t$$

P1.iii

Dependent Variable: LOG(GDP1)

Method: Panel Least Squares — Sample (adjusted): 2005 2009

Periods included: 5 — Cross-sections included: 23

Total panel (unbalanced) observations: 87

White heteroskedasticity-consistent standard errors & covariance

Variable	Coefficient	Std. Error	t-Stat	Prob.
C	-3.191524	14.3006	-0.223	0.8242
LOG(GDP1(-1))	-0.518578	0.051959	-9.981	0
LOG(S_EU(-7))	0.051792	0.018135	2.856	0.0059
LOG(INVR1)	0.183242	0.029858	6.1372	0
TimeTrend	0.003193	0.007316	0.4364	0.6641

Effects Specification — Cross-section fixed (dummy variables)

R-squared	0.895327	Mean dependent	0.036684
Adjusted R-squared	0.849968	S.D. dependent v	0.052878
S.E. of regression	0.020482	Akaike info criter	-4.68945
Sum squared resid	0.02517	Schwarz criterion	-3.92417
Log likelihood	230.991	Hannan-Quinn cr	-4.38129
F-statistic	19.73891	Durbin-Watson st	1.8922
Prob(F-statistic)	0		

$$\ln(\frac{GDP_{i,t}}{GDP_{i,}})=\ln(GDP_{i,t-1})+\ln(INVR_{i,t})+\ln(S\,\&\,E_{i,t-lag})+\log(pop_{i,t})+\tau+a_i+\varepsilon_t$$

P1.iv

Dependent Variable: LOG(GDP1)

Method: Panel Least Squares — Sample (adjusted): 2005 2009

Periods included: 5 — Cross-sections included: 26

Total panel (unbalanced) observations: 120

White heteroskedasticity-consistent standard errors & covariance

Variable	Coefficient	Std. Error	t-Stat	Prob.
C	-5.041678	0.793267	-6.356	0
LOG(GDP1(-1))	-0.429596	0.046348	-9.269	0
LOG(S_EO(-7))	0.021943	0.012078	1.8167	0.0726
LOG(INVR1)	0.210665	0.017174	12.267	0
LOG(POP)	0.443657	0.044538	9.9614	0

Effects Specification — Cross-section fixed (dummy variables)

R-squared	0.839173	Mean dependent	0.04345
Adjusted R-squared	0.787351	S.D. dependent v	0.045341
S.E. of regression	0.020908	Akaike info criter	-4.68503
Sum squared resid	0.039344	Schwarz criterion	-3.98815
Log likelihood	311.1015	Hannan-Quinn cr	-4.40202
F-statistic	16.19339	Durbin-Watson st	1.941622
Prob(F-statistic)	0		

P2.i

$$\ln\left(\frac{GDP_{i,t}}{GDP_{i,t-1}}\right) = C + \ln(GDP_{i,t-1}) + \ln\left(\frac{CAP_{i,t}}{CAP_{i,t-1}}\right) + \ln\left(\frac{UNEM_{i,t}}{UNEM_{i,t-1}}\right) + \ln(OTHGR_{i,t-lag}) + \ln(S\&E_{i,t-lag}) + a_i + \varepsilon_i$$

Dependent Variable: LOG(GDP1/GDP1(-1))
Method: Panel Least Squares — Sample (adjusted): 2004 2009
Periods included: 6 — Cross-sections included: 23
Total panel (unbalanced) observations: 105
White heteroskedasticity-consistent standard errors & covariance

Variable	Coef.	Std. Error	t-Stat	Prob.
C	1.192836	0.769941	1.549257	0.1254
LOG(GDP1(-1))	-0.219691	0.067018	-3.278094	0.0016
LOG(CAP/CAP(-1))	0.089515	0.020955	4.27183	0.0001
LOG(UNEM/UNEM(-1))	-0.106438	0.01259	-8.453896	0
LOG(OTHU(-6))	0.032625	0.016876	1.933251	0.0569
LOG(S_EU(-6))	0.072085	0.024001	3.003418	0.0036

Effects Specification — Cross-section fixed (dummy variables)

R-squared	0.805894	Mean dependent var	0.042513
Adjusted R-squared	0.73783	S.D. dependent var	0.047719
S.E. of regression	0.024433	Akaike info criterion	-4.362569
Sum squared resid	0.045968	Schwarz criterion	-3.654846
Log likelihood	257.0349	Hannan-Quinn criter.	-4.075785
F-statistic	11.84037	Durbin-Watson stat	2.108655
Prob(F-statistic)	0		

P2.i(b)

$$\ln\left(\frac{GDP_{i,t}}{GDP_{i,t-1}}\right) = C + \ln(GDP_{i,t-1}) + \ln\left(\frac{CAP_{i,t}}{CAP_{i,t-1}}\right) + \ln\left(\frac{UNEM_{i,t}}{UNEM_{i,t-1}}\right) + \ln(OTHGR_{i,t-lag}) + \ln(S\&E_{i,t-lag}) + a_i + \tau + \varepsilon_i$$

Dependent Variable: LOG(GDP1/GDP1(-1))
Method: Panel Least Squares — Sample (adjusted): 2004 2009
Periods included: 6 — Cross-sections included: 23
Total panel (unbalanced) observations: 105
White heteroskedasticity-consistent standard errors & covariance

Variable	Coef.	Std. Error	t-Stat	Prob.
C	-12.6673	8.090657	-1.56567	0.1216
LOG(GDP1(-1))	-0.311577	0.074113	-4.204064	0.0001
LOG(CAP/CAP(-1))	0.105676	0.020973	5.038693	0
LOG(UNEM/UNEM(-1))	-0.106656	0.012424	-8.584904	0
LOG(OTHU(-6))	0.032799	0.01852	1.771056	0.0806
LOG(S_EU(-6))	0.068153	0.024114	2.826326	0.006
TimeTrend	0.007393	0.004192	1.763641	0.0818

Effects Specification — Cross-section fixed (dummy variables)

R-squared	0.810648	Mean dependent var	0.042513
Adjusted R-squared	0.740887	S.D. dependent var	0.047719
S.E. of regression	0.02429	Akaike info criterion	-4.36832
Sum squared resid	0.044842	Schwarz criterion	-3.635321
Log likelihood	258.3368	Hannan-Quinn criter.	-4.071294
F-statistic	11.62032	Durbin-Watson stat	2.045625
Prob(F-statistic)	0		

P2.ii

$$\ln\left(\frac{GDP_{i,t}}{GDP_{i,t-1}}\right) = C + \ln(GDP_{i,t-1}) + \ln\left(\frac{INVR_{i,t}}{INVR_{i,t-1}}\right) + \ln\left(\frac{UNEM_{i,t}}{UNEM_{i,t-1}}\right) + \ln(OTHGR_{i,t-lag}) + \ln(S\&E_{i,t-lag}) + a_i + \varepsilon_i$$

Dependent Variable: LOG(GDP1/GDP1(-1))
Method: Panel Least Squares — Sample (adjusted): 2004 2009
Periods included: 6 — Cross-sections included: 23
Total panel (unbalanced) observations: 110
White heteroskedasticity-consistent standard errors & covariance

Variable	Coef.	Std. Error	t-Stat	Prob.
C	0.39329	0.411775	0.955109	0.3423
LOG(GDP1(-1))	-0.152075	0.042549	-3.574152	0.0006
LOG(INVR1/INVR1(-1))	0.197145	0.025073	7.862795	0
LOG(UNEM/UNEM(-1))	-0.045464	0.015537	-2.926219	0.0044
LOG(OTHU(-6))	0.051688	0.027494	1.879995	0.0637
LOG(S_EU(-6))	0.061689	0.029987	2.05723	0.0428

Effects Specification — Cross-section fixed (dummy variables)

R-squared	0.885556	Mean dependent var	0.039783
Adjusted R-squared	0.847873	S.D. dependent var	0.049902
S.E. of regression	0.019464	Akaike info criterion	-4.825214
Sum squared resid	0.031064	Schwarz criterion	-4.137819
Log likelihood	293.3868	Hannan-Quinn criter.	-4.546403
F-statistic	23.5002	Durbin-Watson stat	1.895403
Prob(F-statistic)	0		

P2.ii(b)

$$\ln\left(\frac{GDP_{i,t}}{GDP_{i,t-1}}\right) = C + \ln(GDP_{i,t-1}) + \ln\left(\frac{INVR_{i,t}}{INVR_{i,t-1}}\right) + \ln\left(\frac{UNEM_{i,t}}{UNEM_{i,t-1}}\right) + \ln(OTHGR_{i,t-lag}) + \ln(S\&E_{i,t-lag}) + a_i + \tau + \varepsilon_i$$

Dependent Variable: LOG(GDP1/GDP1(-1))
Method: Panel Least Squares — Sample (adjusted): 2004 2009
Periods included: 6 — Cross-sections included: 23
Total panel (unbalanced) observations: 110
White heteroskedasticity-consistent standard errors & covariance

Variable	Coef.	Std. Error	t-Stat	Prob.
C	-8.924082	5.074403	-1.758647	0.0824
LOG(GDP1(-1))	-0.210635	0.041782	-5.04133	0
LOG(INVR1/INVR1(-1))	0.19982	0.023662	8.444832	0
LOG(UNEM/UNEM(-1))	-0.047572	0.01531	-3.107291	0.0026
LOG(OTHU(-6))	0.048479	0.029144	1.663442	0.1001
LOG(S_EU(-6))	0.05697	0.029489	1.93191	0.0569
TimeTrend	0.004982	0.002648	1.881281	0.0635

Effects Specification — Cross-section fixed (dummy variables)

R-squared	0.887926	Mean dependent var	0.039783
Adjusted R-squared	0.849185	S.D. dependent var	0.049902
S.E. of regression	0.019379	Akaike info criterion	-4.827965
Sum squared resid	0.030421	Schwarz criterion	-4.116021
Log likelihood	294.5381	Hannan-Quinn criter.	-4.539197
F-statistic	22.91926	Durbin-Watson stat	1.83845
Prob(F-statistic)	0		

$$\ln(\frac{GDP_{i,j,t}}{GDP_{i,j,t-1}}) = C + \ln(GDP_{i,j,t-1}) + \ln(\frac{INVR_{i,j,t}}{INVR_{i,j,t-1}}) + \ln(\frac{LABOR_{i,j,t}}{LABOR_{i,j,t-1}}) + \ln(\frac{OTHR_{i,j,t}}{OTHR_{i,j,t}}) + \ln(S\&E_{i,j,t-lag}) + \alpha_i + \varepsilon_i$$

P2.iii

Dependent Variable: LOG(GDP1/GDP1(-1))

Method: Panel Least Squares — Sample (adjusted): 2004 2009

Periods included: 5 — Cross-sections included: 23

Total panel (unbalanced) observations: 87

White heteroskedasticity-consistent standard errors & covariance

Variable	Coef.	Std. Error	t-Stat	Prob.
C	1.039376	0.587105	1.770342	0.0818
LOG(GDP1(-1))	-0.198488	0.067375	-2.946015	0.0046
LOG(INVR1/INVR1(-1))	0.237862	0.02403	9.898422	0
LOG(LABOR/LABOR(-1))	0.007199	0.169839	0.042387	0.9663
LOG(OTHU(-7))	0.043888	0.024077	1.822826	0.0734
LOG(S_EU(-7))	0.054123	0.019607	2.76045	0.0077

Effects Specification — Cross-section fixed (dummy variables)

R-squared	0.91427	Mean dependent var	0.036684
Adjusted R-squared	0.875038	S.D. dependent var	0.052878
S.E. of regression	0.018692	Akaike info criterion	-4.866102
Sum squared resid	0.020615	Schwarz criterion	-4.072477
Log likelihood	239.6754	Hannan-Quinn criter.	-4.546534
F-statistic	23.304	Durbin-Watson stat	2.245071
Prob(F-statistic)	0		

$$\ln(\frac{GDP_{i,j,t}}{GDP_{i,j,t-1}}) = C + \ln(GDP_{i,j,t-1}) + \ln(\frac{INVR_{i,j,t}}{INVR_{i,j,t-1}}) + \ln(\frac{LABOR_{i,j,t}}{LABOR_{i,j,t-1}}) + \ln(\frac{OTHR_{i,j,t}}{OTHR_{i,j,t}}) + \ln(S\&E_{i,j,t-lag}) + \alpha_i + \tau + \varepsilon_i$$

P2.iii(b)

Dependent Variable: LOG(GDP1/GDP1(-1))

Method: Panel Least Squares — Sample (adjusted): 2004 2009

Periods included: 5 — Cross-sections included: 23

Total panel (unbalanced) observations: 87

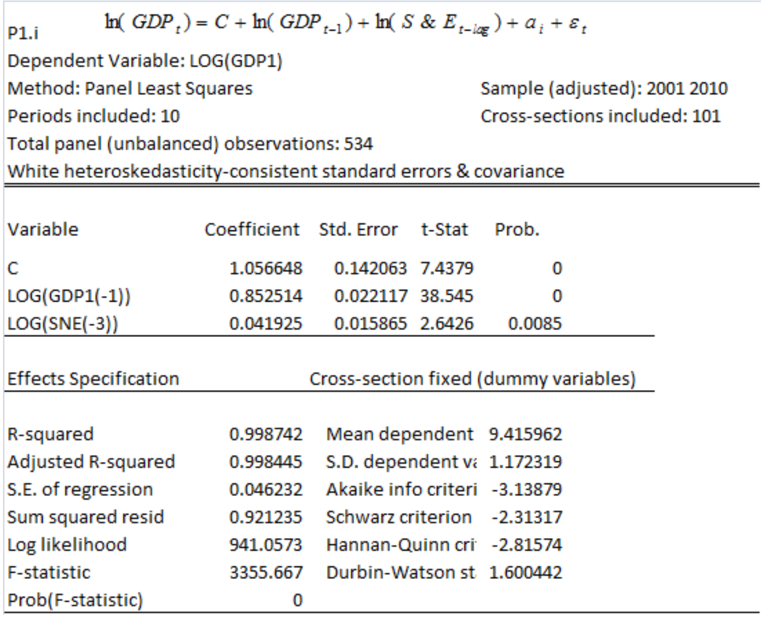
White heteroskedasticity-consistent standard errors & covariance

Variable	Coef.	Std. Error	t-Stat	Prob.
C	-5.485563	10.30098	-0.532528	0.5964
LOG(GDP1(-1))	-0.237436	0.03232	-7.346318	0
LOG(INVR1/INVR1(-1))	0.241643	0.028532	8.469057	0
LOG(LABOR/LABOR(-1))	0.047536	0.185491	0.256271	0.7986
LOG(OTHU(-7))	0.042484	0.023612	1.79928	0.0772
LOG(S_EU(-7))	0.052828	0.020355	2.595325	0.012
TimeTrend	0.003463	0.005171	0.669718	0.5057

Effects Specification — Cross-section fixed (dummy variables)

R-squared	0.914912	Mean dependent var	0.036684
Adjusted R-squared	0.873834	S.D. dependent var	0.052878
S.E. of regression	0.018782	Akaike info criterion	-4.850624
Sum squared resid	0.02046	Schwarz criterion	-4.028655
Log likelihood	240.0021	Hannan-Quinn criter.	-4.519642
F-statistic	22.27299	Durbin-Watson stat	2.197718
Prob(F-statistic)	0		

Model Results With Data Set 2 – All Countries



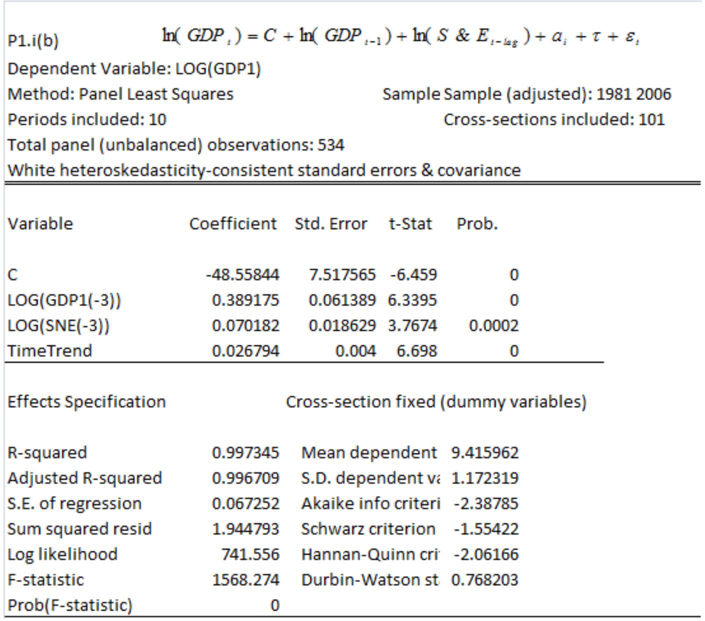
P1.i $\ln(GDP_t) = C + \ln(GDP_{t-1}) + \ln(S\,\&\,E_{t-lag}) + a_i + \varepsilon_t$

Dependent Variable: LOG(GDP1)
Method: Panel Least Squares
Sample (adjusted): 2001 2010
Periods included: 10
Cross-sections included: 101
Total panel (unbalanced) observations: 534
White heteroskedasticity-consistent standard errors & covariance

Variable	Coefficient	Std. Error	t-Stat	Prob.
C	1.056648	0.142063	7.4379	0
LOG(GDP1(-1))	0.852514	0.022117	38.545	0
LOG(SNE(-3))	0.041925	0.015865	2.6426	0.0085

Effects Specification — Cross-section fixed (dummy variables)

R-squared	0.998742	Mean dependent	9.415962
Adjusted R-squared	0.998445	S.D. dependent va	1.172319
S.E. of regression	0.046232	Akaike info criteri	-3.13879
Sum squared resid	0.921235	Schwarz criterion	-2.31317
Log likelihood	941.0573	Hannan-Quinn cri	-2.81574
F-statistic	3355.667	Durbin-Watson st	1.600442
Prob(F-statistic)	0		



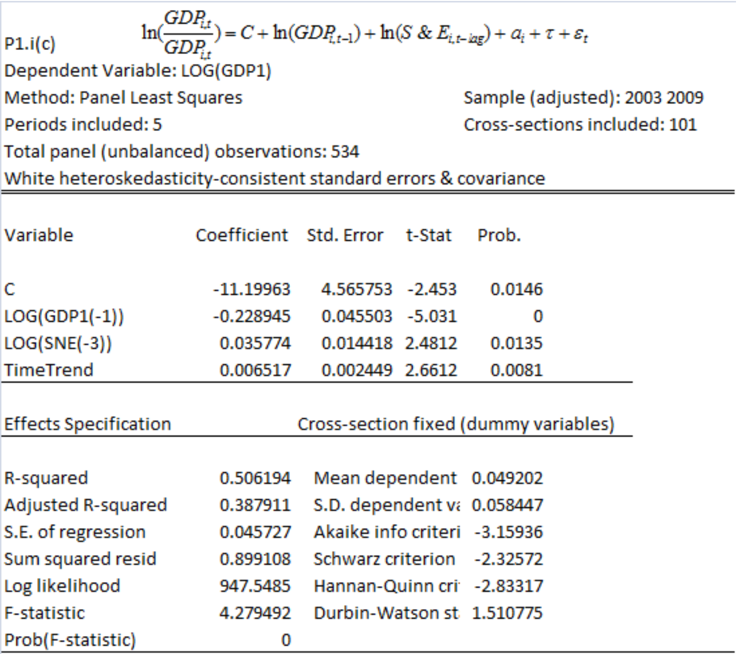
P1.i(b) $\ln(GDP_t) = C + \ln(GDP_{t-1}) + \ln(S\,\&\,E_{t-lag}) + a_i + \tau + \varepsilon_t$

Dependent Variable: LOG(GDP1)
Method: Panel Least Squares
Sample Sample (adjusted): 1981 2006
Periods included: 10
Cross-sections included: 101
Total panel (unbalanced) observations: 534
White heteroskedasticity-consistent standard errors & covariance

Variable	Coefficient	Std. Error	t-Stat	Prob.
C	-48.55844	7.517565	-6.459	0
LOG(GDP1(-3))	0.389175	0.061389	6.3395	0
LOG(SNE(-3))	0.070182	0.018629	3.7674	0.0002
TimeTrend	0.026794	0.004	6.698	0

Effects Specification — Cross-section fixed (dummy variables)

R-squared	0.997345	Mean dependent	9.415962
Adjusted R-squared	0.996709	S.D. dependent va	1.172319
S.E. of regression	0.067252	Akaike info criteri	-2.38785
Sum squared resid	1.944793	Schwarz criterion	-1.55422
Log likelihood	741.556	Hannan-Quinn cri	-2.06166
F-statistic	1568.274	Durbin-Watson st	0.768203
Prob(F-statistic)	0		



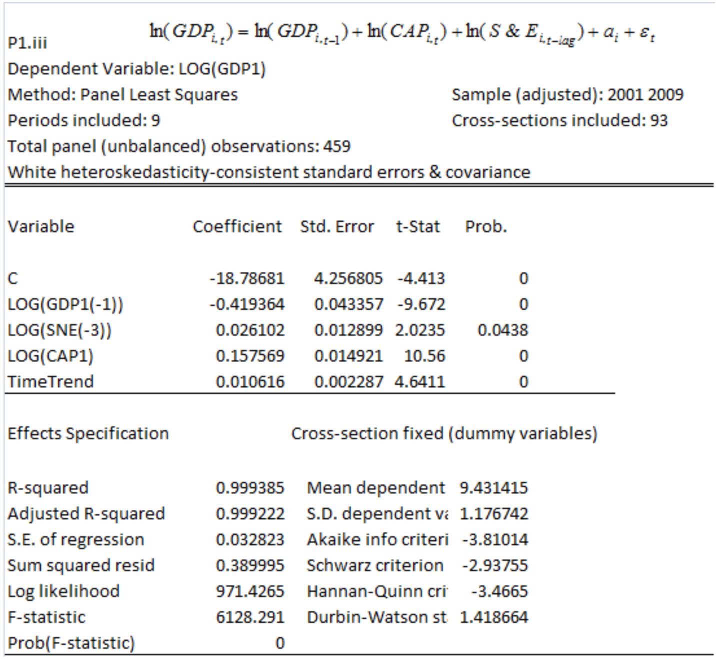
P1.i(c) $\ln(\frac{GDP_{i,t}}{GDP_{i,t}}) = C + \ln(GDP_{i,t-1}) + \ln(S\,\&\,E_{i,t-lag}) + a_i + \tau + \varepsilon_t$

Dependent Variable: LOG(GDP1)
Method: Panel Least Squares
Sample (adjusted): 2003 2009
Periods included: 5
Cross-sections included: 101
Total panel (unbalanced) observations: 534
White heteroskedasticity-consistent standard errors & covariance

Variable	Coefficient	Std. Error	t-Stat	Prob.
C	-11.19963	4.565753	-2.453	0.0146
LOG(GDP1(-1))	-0.228945	0.045503	-5.031	0
LOG(SNE(-3))	0.035774	0.014418	2.4812	0.0135
TimeTrend	0.006517	0.002449	2.6612	0.0081

Effects Specification — Cross-section fixed (dummy variables)

R-squared	0.506194	Mean dependent	0.049202
Adjusted R-squared	0.387911	S.D. dependent va	0.058447
S.E. of regression	0.045727	Akaike info criteri	-3.15936
Sum squared resid	0.899108	Schwarz criterion	-2.32572
Log likelihood	947.5485	Hannan-Quinn cri	-2.83317
F-statistic	4.279492	Durbin-Watson st	1.510775
Prob(F-statistic)	0		



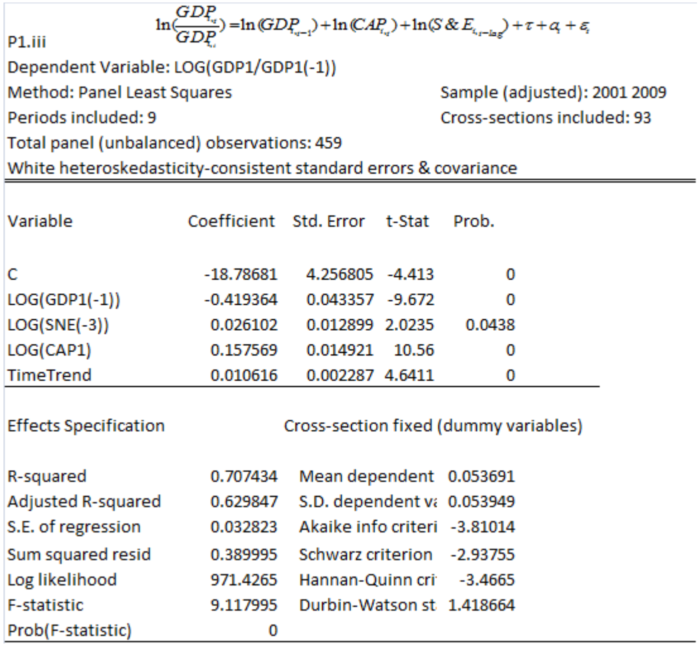
P1.iii $\ln(GDP_{i,t}) = \ln(GDP_{i,t-1}) + \ln(CAP_{i,t}) + \ln(S\,\&\,E_{i,t-lag}) + a_i + \varepsilon_t$

Dependent Variable: LOG(GDP1)
Method: Panel Least Squares
Sample (adjusted): 2001 2009
Periods included: 9
Cross-sections included: 93
Total panel (unbalanced) observations: 459
White heteroskedasticity-consistent standard errors & covariance

Variable	Coefficient	Std. Error	t-Stat	Prob.
C	-18.78681	4.256805	-4.413	0
LOG(GDP1(-1))	-0.419364	0.043357	-9.672	0
LOG(SNE(-3))	0.026102	0.012899	2.0235	0.0438
LOG(CAP1)	0.157569	0.014921	10.56	0
TimeTrend	0.010616	0.002287	4.6411	0

Effects Specification — Cross-section fixed (dummy variables)

R-squared	0.999385	Mean dependent	9.431415
Adjusted R-squared	0.999222	S.D. dependent va	1.176742
S.E. of regression	0.032823	Akaike info criteri	-3.81014
Sum squared resid	0.389995	Schwarz criterion	-2.93755
Log likelihood	971.4265	Hannan-Quinn cri	-3.4665
F-statistic	6128.291	Durbin-Watson st	1.418664
Prob(F-statistic)	0		



P1.iii $\ln(\frac{GDP_{i,t}}{GDP_{i,t}}) = \ln(GDP_{i,t-1}) + \ln(CAP_{i,t}) + \ln(S\&E_{i,t-lag}) + \tau + \alpha_i + \varepsilon_i$

Dependent Variable: LOG(GDP1/GDP1(-1))

Method: Panel Least Squares — Sample (adjusted): 2001 2009

Periods included: 9 — Cross-sections included: 93

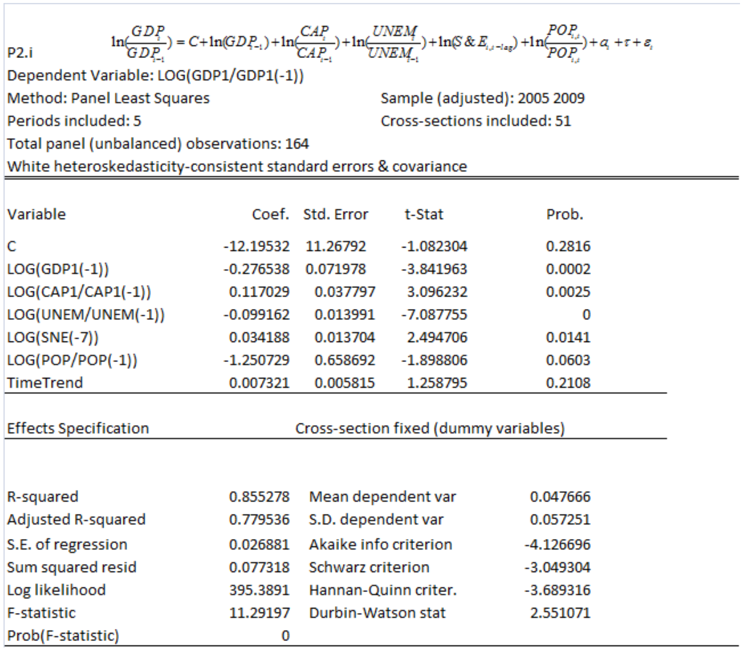
Total panel (unbalanced) observations: 459

White heteroskedasticity-consistent standard errors & covariance

Variable	Coefficient	Std. Error	t-Stat	Prob.
C	-18.78681	4.256805	-4.413	0
LOG(GDP1(-1))	-0.419364	0.043357	-9.672	0
LOG(SNE(-3))	0.026102	0.012899	2.0235	0.0438
LOG(CAP1)	0.157569	0.014921	10.56	0
TimeTrend	0.010616	0.002287	4.6411	0

Effects Specification — Cross-section fixed (dummy variables)

R-squared	0.707434	Mean dependent	0.053691
Adjusted R-squared	0.629847	S.D. dependent va	0.053949
S.E. of regression	0.032823	Akaike info criteri	-3.81014
Sum squared resid	0.389995	Schwarz criterion	-2.93755
Log likelihood	971.4265	Hannan-Quinn cri	-3.4665
F-statistic	9.117995	Durbin-Watson st	1.418664
Prob(F-statistic)	0		



P2.i $\ln(\frac{GDP_t}{GDP_{t-1}}) = C + \ln(GDP_{t-1}) + \ln(\frac{CAP_t}{CAP_{t-1}}) + \ln(\frac{UNEM_t}{UNEM_{t-1}}) + \ln(S\&E_{i,t-lag}) + \ln(\frac{POP_{i,t}}{POP_{i,t}}) + \alpha_i + \tau + \varepsilon_i$

Dependent Variable: LOG(GDP1/GDP1(-1))

Method: Panel Least Squares — Sample (adjusted): 2005 2009

Periods included: 5 — Cross-sections included: 51

Total panel (unbalanced) observations: 164

White heteroskedasticity-consistent standard errors & covariance

Variable	Coef.	Std. Error	t-Stat	Prob.
C	-12.19532	11.26792	-1.082304	0.2816
LOG(GDP1(-1))	-0.276538	0.071978	-3.841963	0.0002
LOG(CAP1/CAP1(-1))	0.117029	0.037797	3.096232	0.0025
LOG(UNEM/UNEM(-1))	-0.099162	0.013991	-7.087755	0
LOG(SNE(-7))	0.034188	0.013704	2.494706	0.0141
LOG(POP/POP(-1))	-1.250729	0.658692	-1.898806	0.0603
TimeTrend	0.007321	0.005815	1.258795	0.2108

Effects Specification — Cross-section fixed (dummy variables)

R-squared	0.855278	Mean dependent var	0.047666
Adjusted R-squared	0.779536	S.D. dependent var	0.057251
S.E. of regression	0.026881	Akaike info criterion	-4.126696
Sum squared resid	0.077318	Schwarz criterion	-3.049304
Log likelihood	395.3891	Hannan-Quinn criter.	-3.689316
F-statistic	11.29197	Durbin-Watson stat	2.551071
Prob(F-statistic)	0		

Curriculum Vitae

Nathaniel Robinson, P.E. has worked for 10 years in engineering and project management. He began his engineering profession as a design engineer at Motorola working on RF and microcontroller design before spending six years working on Department of Defense projects in electromagnetic design and application. Prior to joining UTEP's Center for Space Exploration and Technology Research (*c*SETR), he worked on the testing of space shuttle thrusters and various propulsion tests at NASA White Sands Test Facility. At *c*SETR, he serves as Associate Director managing research in energy, propulsion and aerostructures. He is also the Director of the NASA Science, Engineering, Math and Aerospace Academy for the Southwest at UTEP. Previously an international volunteer in humanitarian aid, he has also spoken and published in various technical, education and social activist conferences.