DOES GEOGRAPHY MATTER? Contributions of Agriculture to Economic Development and Growth: A Counterfactual Approach

by

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B.A. (Honours), Simon Fraser University 2000

PROJECT SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF

MASTERS OF ARTS
In the
Department
of
Economics

SIMON FRASER UNIVERSITY

Spring 2005

APPROVAL

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Degree:	**M. A. (Economics)**
Title of Project:	**Does Geography Matter? Contributions Of Agriculture To Economic Development And Growth: A Counterfactual Approach**

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ABSTRACT

Jared Diamond in his Pulitzer Prize winning book, “Guns, Germs, and Steel,” attributes the differences in worldwide income and wealth largely to geographical advantages. He argues that Eurasian economies are further developed than others because they benefited from an environment easier to manipulate, especially in terms of animal and plant domestication. As a template for his theory, Diamond cites the divergent development paths of the Maori and the Moriori; South Pacific peoples that originated from a common ancestor but whose economies evolved in completely opposite directions as a result of the geographical attributes of the islands they came to colonize in isolation of one another. It is this claim that has led me to the topic of this paper. I aim to test the relevance of Diamond’s hypothesis for countries of today. That is, is geography – proxied by agriculture – still crucial in steering societies onto a path of economic growth?

DEDICATION

To James and Olivia King, whose love and support make everything possible.

ACKNOWLEDGEMENTS

Many thanks to Steve Easton, whose time and patience made this project possible. His wonderful attitude and intellectual guidance helped me to develop the invaluable skills I needed to get through the many obstacles I faced during my time here. I would also like to thank Clyde Reed for giving me perspective on our discipline and life in general.

And a very special thanks to Daljit Dhadwal and Dot Wong for their support and friendship.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

I INTRODUCTION

Recognizing the impact of geography on economic development is not a recent phenomenon. In addition to his emphasis on economic institutions, Adam Smith recognized its crucial role in determining the extent of the market as increased specialization and productivity is inconsequential if output cannot be brought to markets physically and economically unfettered. David Ricardo saw geography as determining the limits of economic growth via the extent of food cultivation arguing that as the demand for food increases, poorer lands are brought in to cultivate food which consequently raises the costs of production, reduces profits, inflates rents and crowds out other uses for capital.

More recently, Jared Diamond in his Pulitzer Prize winning book, "Guns, Germs, and Steel," attributes the differences in worldwide income and wealth largely to geographical advantages. He argues that Eurasian economies are further developed than others because they benefited from an environment easier to manipulate, especially in terms of animal and plant domestication. As a template for his theory, Diamond cites the divergent development paths of the Maori and the Moriori; South Pacific peoples that originated from a common ancestor but whose economies evolved in completely opposite directions as a result of the geographical attributes of the islands they came to colonize in isolation of one another.

It is this claim that has led me to the topic of this paper. I aim to test the relevance of Diamond's hypothesis for countries of today. That is, is geography – proxied by agriculture – still crucial in steering societies onto a path of material well-being? Will improvements in a nation's agricultural productivity lead to increases in its economic growth?

This paper is organized as follows: the first section will provide a brief description of divergent development paths of the Maori and the Moriori, while the second details the theory of how agricultural productivity contributes to economic growth. Then the model by which I test this theory is introduced and derived in section three followed by a section devoted to a discussion of the estimation methods used as well as the results. Conclusions are made in section five.

I A NATURAL EXPERIMENT IN THE SOUTH PACIFIC

The evolutionary history of the Moriori and the Maori presents us with results equivalent to that of a laboratory–type experiment that tests how agriculture affects the growth of an economy. Despite the fact that they both originated from Polynesian farmers in New Zealand, they evolved in completely opposite directions after they separated from one another.

North Island was colonized by the Maori who continued to improve upon the agricultural techniques of their ancestors. As a result, they enjoyed tremendous agricultural surpluses that enabled them to support an increasingly complex society in which food was not the main priority. Because their surpluses could be stored and redistributed, they were able to spare members of their society to engage and specialize in other activities like crafts, law, religion, war and art. Their population, which peaked at more than one hundred thousand, developed and refined the necessary technologies in water transport, weaponry, and warfare to conquer and take from the neighbouring populations. Thus, the average Maori enjoyed a life that was considerably more comfortable in terms of material goods than any of their neighbours.

Conversely, the Moriori, who colonized the Chatham Islands, abandoned the farming practices of their ancestors and reverted to hunting and gathering because the harsh cold climate of the island did not allow their traditional crops to grow, and daunting geographical barriers like the immense ocean prohibited access to other islands for colonization.[1] Consequently, their population never reached more than 2000 since they rarely enjoyed surpluses for storage and redistribution; each household unit produced what it needed so very few activities were specialized. Their simple subsistence economy required that they become cooperative if they were to survive, so they renounced war and reduced potential conflicts from overpopulation by using castration as a means of birth control. Thus the Moriori evolved into a small, unwarlike population with very simple technology, weapons and organization – characteristics that ironically led to their demise. By December of 1835, the Moriori were being slaughtered, enslaved and exploited by their North Island Maori cousins who had navigated their way to the isolated island in search of resources to enhance their wealth.

Thus the experience of the Maori and the Moriori strongly suggests that indeed, agriculture exerts considerable influence on the rate of economic growth; two populations that initially shared the same culture, language and technology evolved on completely divergent paths because of it. Immediately, the question that comes to mind is "Does agriculture still exert the same degree of influence on countries of today?"

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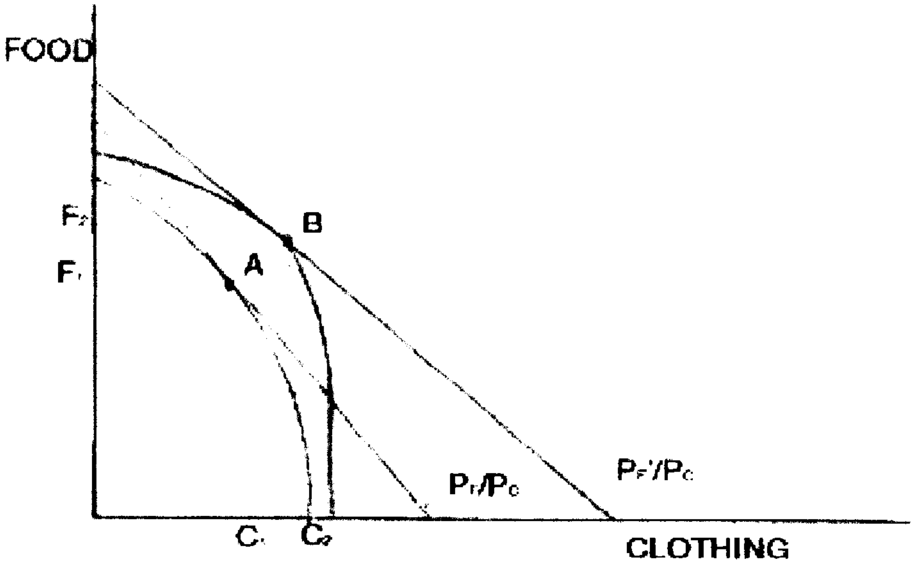
[1] It's been theorized by anthropologists that the Moriori arrived on the Chatham Islands by accident i.e. shipwreck

II THE THEORY

The theory of how agriculture influences economic growth is quite straightforward and intuitive. Assuming an economy with only two sectors, agriculture and manufacture, and only two goods, say food and clothing, an exogenous technology shock that improves agricultural productivity is expected to increase the supply of food which should, all else constant, decrease its price P_F. This decrease in the price of food is equivalent to an increase in real income but because food is relatively demand inelastic, consumers increase their demand for manufactured goods like clothing. Consequently, this increase in the demand for clothing, all else constant, drives up its price, P_C , and attracts more firms into the sector who, driven by the profit motive, increase its supply. Thus, outputs in both sectors increase. This output effect can be seen through the Figure 1:

Figure 1: The Output Effect of a Positive Agricultural Technology Shock



Initially the two-sector economy is producing food and clothing at F_1 and C_1 (point A).

A positive technology shock affecting only the agricultural sector pushes the production possibilities frontier outward improving productivity and hence increases the output of food. All else constant, an increase in the supply of food is expected to decrease its price resulting in a less steeper price ratio. Production levels move the point B where output levels are at F_2 and C_2. Thus the output effect of this positive technology shock to sector A has increased the production of both F and C.

Simultaneously, there is a factor transfer effect. Assuming this economy only has two factors of production that are completely and perfectly mobile[2] - labour (L) and capital (K) – it is expected that an increase in agricultural productivity will decrease the demand for labour since now, more food can be produced with less labour. Consequently, labour is released from the agricultural sector and becomes available for the manufacturing sector resulting in a decrease in the agricultural share of the total labour force while the

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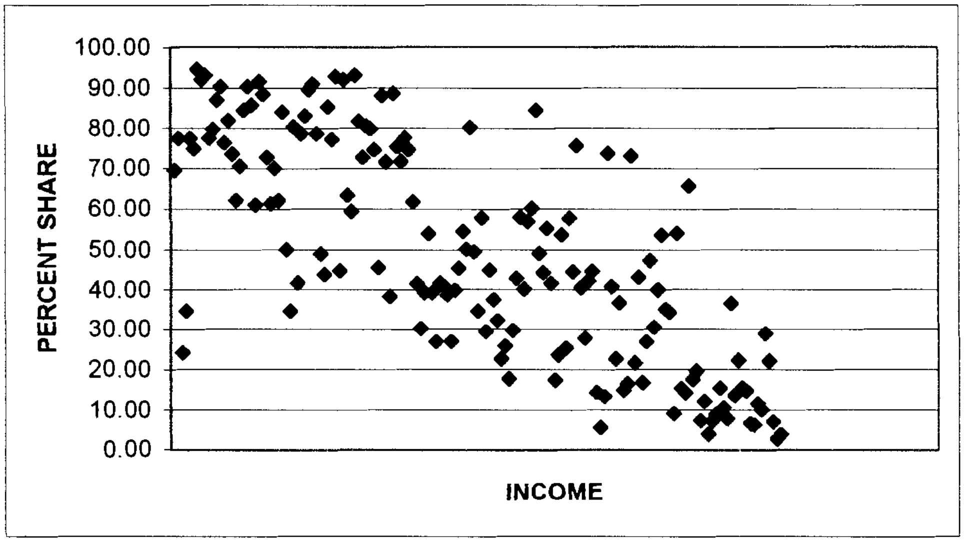
[2] I am completely aware of the absurdity of this assumption. However, it is made for simplification purposes so that the dynamics of the theoretical model can be seen with more clarity.

manufacturing share will increase. Capital inputs are also reallocated in the same way by the same logic.

The relationship between agricultural share of the labour force and national income are presented in Figure II below.

Figure 2: Agicultural Share of Total Labour Force: Low, Middle, High Income & OECD Countries in 1975



Source: WDI 2000

Figure II shows that in 1975, for a random sample of 159 countries, the percentage of the total labour force engaged in agricultural activities range from 2.71 to 94.5 with an average of 48.71. This graph gives support to the notion of the *factor transfer effect*; the less people are engaged in the agricultural sector, the more developed its economy is. The agricultural share for low-income countries cluster around 60-90, 40-60 for middle income countries, 20-40 for high-income countries and 0-20 for OECD countries.

III THE MODEL

The theory detailed in the previous section can be represented mathematically and tested using the model proposed by Sherman Robinson in *Sources of Growth in Less Developed Countries: A Cross-Section Study* (1971). To save time, I will present a very brief derivation of the model below. The equation numbers follow that of the full model derivation which can be found in Appendix I.

First, a simple dynamic model is derived from a general production function with only two inputs, capital (K) and labour (L).

$$Y = F(K, L)$$

Taking the time derivative and some algebraic manipulation yields:

(1) $RY = \partial F/\partial K\,(DK/Y) + [(\partial F/\partial L)\,L/Y]\,RL$

Where: R is the rate of growth

Y is per capita real GDP

D is the time derivative

To make estimation by OLS possible, we define (DK/Y) = RINV = the investment rate[3] to get:

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[3] We define (DK/Y) as the investment rate rather than the growth rate of capital because of data limitations.

(2) $RY = \beta_1 RINV + \beta_2 RL$

Then, in order to incorporate the effect of structural change on growth, a two-sector model is developed.

Assume an economy with only two sectors; a relatively large backward agricultural sector and a small nonagricultural sector that, for simplicity, we will define as the manufacturing sector.

Recall that, as specified in the dynamic model, the only factors of production in this economy are capital (K) and labour (L) which are distributed between these two sectors. Assume perfect mobility of these factors between the sectors. After numerous definitions, calculations and algebraic manipulations, we get:

(14) $RY = RY^* + (P_M\, MPK_M - P_A\, MPK_A)\, T_K\, (K/Y) + (P_M\, MPL_M - P_A\, MPL_A)\, T_L\, (L/Y)$

Where: P_M = price of the manufactured good

P_A = price of the agricultural good

MPK_M = marginal Physical Product of K in sector M

MPK_A = marginal Physical Product of K in sector A

MPL_M = marginal Physical Product of L in sector M

MPL_A = marginal Physical Product of L in sector A

T_K = transfer rate of K between sectors[4]

T_L = transfer rate of L between sectors

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[4] The transfer rates of inputs reflect the reallocation of K and L from the relatively less to the more productive sector.

(L/Y) = labour share of total income

(K/Y) = capital share of total income

RY* = economic growth rate if there were no factor mobility

Notice that in the above equation, the second and third terms reflect the contribution of factor transfers from the relatively less to the more productive sector. The differences in the value of the marginal products for labour and capital between the two sectors are a function of technological factors, which are reflected in the spread of marginal physical products, and demand factors, which are reflected in the relative prices of the outputs. Thus, the output effect is embodied in coefficient estimates of factor transfer variables. Equation (14) can be viewed a counterfactual; the growth rate of the economy is dependent on the natural growth rate (which is a function of only the growth rates of its inputs) plus the contributions of factor reallocation when there is a technological or demand shock. This is the equation to be estimated, however a few adjustments must be made before this is possible. Equation (14) must be reformulated so that the variables are defined in measurable quantities. After further definitions and derivatives are taken, we get the following equation:

$$(24)\ \ RY = \beta_0 + \beta_1\ RINV + \beta_2\ RL + \beta_3\ T_K\ (r\ K/Y) + \beta_4\ T_L\ (w\ L/Y)$$

Where: r = average rental rate on K

w = average wage of L

(r K/Y) = capital share of total income

$(w\ L/Y)$ = labour share of total income

T_K = transfer rate of K between sectors

T_L = transfer rate of L between sectors

$\beta_3 = (r_M - r_A) / r$ = % difference in rental rate between the sectors

$\beta_4 = (w_M - w_A) / w$ = % difference in wages between the sectors

Recalling our assumption that sector M is relatively more productive than sector A, we can interpret the last two terms of equation (24) as changes in the manufacturing share of total income as a result of the factor transfer effect. Thus, the equation says that the economy's growth rate is composed of contributions from the growth rate of capital, which we proxied with the investment rate, the growth rate of the labour supply, and the growth rate of the manufacturing sector as a result of a productivity / demand shock that redistributed inputs from sector A to sector M.

Equation (24) is the equation to be estimated. The sample I have chosen consists of 11 developing countries from East and South-East Asia for the period of 1961-1989 to coincide with their disparate adoption of Green Revolution technologies.

Green Revolution technologies, a term coined in the 1960's, refers to a package of agricultural inputs developed exclusively for economically underdeveloped countries battling chronic food shortages. These Green Revolution inputs consisted of high yielding grain varieties (HYV), mainly rice and wheat, heavy chemical use via fertilizers and pesticides, and carefully controlled irrigation. According to Rosset et al (2000), Green Revolution technologies replaced Third World traditional farming practices almost completely by the 1970's with Asian countries being the most receptive.

IV DATA, ESTIMATION AND RESULTS

Due to data limitations, DKS will proxy for T_K (r K/Y) and DLS will proxy for T_L (w L/Y) where DKS is the annual change in the manufacturing share of total GDP and DLS is the annual change in the urbanization rate of the total population. Thus, the model that is estimated is

$$\mathbf{RY_{it} = \beta_0 + \beta_1\ RINV_{it} + \beta_2\ RL_{it} + \beta_3\ DKS_{it} + \beta_4\ DLS_{it}}$$

Where: i = country

t = year (1961-89)

RY_{it} = Annual Rate of Growth of GDP

$RINV_{it}$ = Annual Rate of Investment Growth

RL_{it} = Annual Growth Rate of Labour[5]

DKS_{it} = Annual Change in the Manufacturing[6] Share of GDP

DLS_{it} = Annual Change in Urbanization Rate

Again, I emphasize the intuitive interpretation of the estimating equation. The first two slope coefficients represent the contributions to GDP growth arising from factor input

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[5] Data for this variable was retrieved from the World Bank Growth Research Micro Database; data for the other variables were found in the World Development Index 2000.

[6] DKS was computed by retrieving agricultural share of GDP from the WDI and subtracting that value from 1 since the model has only two sectors. This is considered acceptable since it can be argued that a two-sector economy is not far removed from the reality of most developing countries.

growth – the counterfactual – while the latter two terms reflect the contributions to economic growth by the factor transfer effect; that is, the release of inputs from sector A to sector M as a result of improved agricultural productivity via Green Revolution technologies.

An inspection of the variables plotted against time for each individual cross-section reveals that:

- double digit RY values are rare
- only Pakistan and Sri Lanka had consistently positive or zero RY rates over the sample period
- RINV appears to be the most volatile, especially for many of the East Asian countries in the early 1960's
- the sample range for RINV values are –60.4% (China) to 108.06% (South Korea)
- RL values hover around positive low digits over the sample period
- Only China shows negative RL values – perhaps a reflection of their one child policy?
- DKS values appear to be the second most volatile after RINV
- DLS values appear to be the most stable; they're positive and below 10% except in China in the early 1960's where it's actually negative

A possible reason for China's negative DLS values in the early 60's may be its deteriorating relationship with the Soviet Union[7], which resulted in the latter's withdrawal of financial and technical assistance, and the former's reallocation of its labour force on a massive scale in an effort to become more self sufficient.

China and South Korea's extreme RINV values during the early 60's appear credible although the accuracy of the magnitudes is questionable. China's –60.4% may reflect the results of the Great Leap Forward and the Cultural Revolution experiments, while South Korea's 108% may reflect its highly controversial[8] and interventionist efforts to accelerate industrialization.

Descriptive statistics for the common sample show that China and South Korea are responsible for all but one extreme value. Concerns over whether or not to include them in the sample are addressed further on in the report through a sensitivity analysis. The mean and median values of each variable are equal, or very close to being equal to one another, thereby suggesting a symmetric distribution.

It was also noted that one of the cross-sections, Pakistan, was missing RINV observations for the years 1982 and 1983. Since Pakistan was a key participant in the Green Revolution, it was decided that the benefit of using forecasted values for 1982 and 1983

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[7] Details found in Todaro pp. 229

[8] According to Rodrik (1994), the Chung-Hee Park administration emphasized the expectation that entrepreneurs were to invest in productive activities rather than rent-seeking ones by arresting and imprisoning many of the nation's leading businessmen on the charge of illicit wealth accumulation. They were only set free after their personal commitment to undertake specified investments were extracted.

would outweigh the cost; that is, by being able to keep Pakistan in the sample, the benefit of obtaining more efficient estimates would outweigh the cost of introducing measurement error. Thus RINV values for the missing years were forecasted. Using all the explanatory variables for the years prior, Pakistan's RINV was regressed on its RL, DKS and DLS values and the missing RINV values were computed from the estimated regression. The regression and computations can be found in appendix III. Because these forecasted values appear inconsistent with the rest of the data – they're fairly large and negative - concerns about including Pakistan in the sample will be addressed in a sensitivity analysis.

As previously mentioned, the presented model is taken from a 1971 cross-sectional study where the estimates were obtained by taking the average of each variable the period in question (1958-66) and estimating by OLS. However, estimation can be improved by the use of panel data which is the approach taken in this study. Because combining variation across the cross-sectional units with variation over time creates more variability, more information is incorporated into the estimation procedure, resulting in more efficient estimates and the alleviation of multicollinearity problems.

All output and testing can be found in appendices II and III.

Because with panel data, it's possible to estimate separate equations for each cross-sectional unit, a Chow test for pooling was conducted. With a test stat of F=[(3402.269-1947.813)/5]/[1947.813/(319-5*11)] =39.42641 the null that the intercept and slope coefficients are the same across the equations was rejected at the 5% significance level thereby suggesting that the data should not be pooled together and estimated by OLS.

Nevertheless, in this context, it may still be possible to estimate using pooled data via the seemingly unrelated regression (SUR) method since the countries are linked geographically. That is, it is highly probable that contemporaneous correlation exists among the cross-sectional errors; the impact of the Green Revolution technologies on national income growth is affected by geographical conditions like weather, which is embodied in the error term. Thus, the error term for the regression of one cross-section or country is likely to be correlated with the error term of another, or many other cross-sections in the same time period because they share many similar geographical attributes.

A LM test suggests that indeed contemporaneous correlation between the error terms across some or all equations does exist. The null of no contemporaneous correlation was rejected at the 5% significance level with a test statistic of 99.974 thereby suggesting that, by pooling the data and estimating by the SUR technique, more efficient estimates can be obtained because additional information – that is, that the error terms across equations are contemporaneously correlated – is incorporated into the estimation procedure.

Of course in pooling the data and estimating the equations jointly, the problem of heteroskedasticity must be addressed. The SUR technique does this by estimating the variance-covariance matrix in the context of contemporaneous correlation and then estimating the coefficients by GLS. Therefore, SUR estimates are a result of GLS, not OLS.

An examination of the estimated coefficients and corresponding standard errors obtained from the two methods discussed are given in Table 1 below. As it can be seen, the standard errors obtained from using the SUR technique are smaller than of those obtained using OLS. Therefore, in estimating these equations jointly with SUR, more efficient estimates were indeed obtained.

Again, I emphasize the intuitive interpretation of the estimating equation. The first two slope coefficients represent the additional expected annual growth rate of GDP arising from a unit of factor input growth – the counterfactual – while the latter two slope coefficients reflect the contributions to national income growth by the factor transfer effect; that is, the release of inputs from the agricultural sector to the manufacturing section as a result of improved agricultural productivity via Green Revolution technologies.

Table 1: Summary of Estimation Results

Dependent Variable: ?RY
Sample: 1961 1989
Included observations: 29
Number of cross-sections used: 11
Total panel (balanced) observations: 319

INDEPENDENT VARIABLES	POOLED OLS White Heteroskedasticity-Consistency Std Errors	SUR 1	SUR 2
CONSTANT	3.114135 (0.611819)	2.152280 (0.329925)	3.361136 (0.392861)
RINV	0.122891 (0.019302)	0.126962 (0.008370)	0.122426 (0.008382)
RL	1.243794 (0.341326)	1.023302 (0.137364)	1.072819 (0.156475)
DKS	0.204909 (0.079390)	-	0.156644 (0.041518)
DLS	-0.358580 (0.174656)	-	-0.349102 (0.085810)
Adjusted R^2	0.410946	0.357390	0.407123

Standard errors of the estimated coefficients are in parentheses.

All estimates in models SUR 1 and SUR 2 are statistically significant with p-values of zero.

Although it may appear that the values of the estimated coefficients are negligible, it must be remembered that they are interpreted as percent contributions to the rate of GDP growth. Thus, given that average income growth rates for nations, developed or developing, are rarely ever double digits, the size of the estimates are reasonable. Over time, the size of such contributions can be quite influential.

SUR1 is the counterfactual – it estimates the hypothetical situation in which no positive agricultural technology shock occurred. All of the estimated coefficients are significant, and it appears that factor growth explains about 36 percent of the variability in annual GDP growth. According to the model, a 1% increase in the labour growth rate (RL) is expected to bring about a 1% increase to annual GDP growth (RY) – a contribution of considerable magnitude, especially relative to the other variables. Curiously, a 1% rise in the investment rate (RINV), all else constant, would only bring about a 0.12% rise in RY. A possible reason for this may be that in developing countries, labour is more abundant than capital thus, they are more reliant on this cheaper input than high maintenance physical capital. A Wald test indicates that jointly, these factor growth variables are statistically significant with a test statistic of F=147.2947 and p-value of zero.

SUR 2 is the derived model that reveals the impact of factor transfers on national income growth as a result of implementing Green Revolution technologies. According to the results, factor reallocation explains approximately 5% of the variability in annual GDP growth. As in model SUR 1, the magnitude of influence wielded by the labour variable is greater than the capital investment variable in terms of absolute value. All else constant, a 1% rise in DKS (the manufacturing share of national income) is expected bring about a 0.16% increase in RY, while a 1% rise in DLS (the urbanization rate) is expected to decrease RY by about 0.35% - a counterintuitive result. This unexpected sign may be an indication of misspecification as RESET tests for the individual cross-sections vary. Perhaps variables that account for human capital like primary school enrollment or literacy rates should be included, although there is likely to be difficulty in obtaining such data since it is costly to collect such observations on an annual basis. Other possible reasons may be a very difficult adjustment period in which the absorption of the transferred labour is slow, or incorrect theory. However, it is more than likely a reflection of the experiment's failure. According to the literature, it appears much of the gains in output and productivity could not be sustained in the long run due to many factors, among them, environmental and health degradation resulting from the misuse and abuse of the Green Revolution technologies. A Wald test suggests that these factor transfer coefficients are indeed simultaneously significant at virtually all significance levels with a test statistic of F=15.81769 and zero p-value.

A sensitivity analysis is presented below:

Table 2: Sensitivity Analysis

Dependent Variable: ?RY
Sample: 1961 1989
Included observations: 29

INDEPENDENT VARIABLE	**1 W/O CHINA**	**2 W/O SOUTH KOREA**	**3 W/O CHINA & S KOREA**	**4 W/O PAKISTAN**
CONSTANT	4.186 (0.492)	3.119 (0.453)	4.079 (0.527)	3.507 (0.440)
RINV	0.104 (0.009)	0.131 (0.009)	0.111 (0.010)	0.133 (0.009)
RL	0.919 (0.183)	1.114 (0.167)	1.000 (0.186)	1.127 (0.179)
DKS	0.114 (0.042)	0.178 (0.048)	0.125 (0.048)	0.156 (0.045)
DLS	-0.404 (0.116)	-0.355 (0.094)	-0.476 (0.125)	-0.433 (0.093)
Adjusted R^2	0.280	0.438	0.308	0.425
# of cross-sections	10	10	9	10
Total panel (balanced) obs.	290	290	261	290

Standard errors of the estimated coefficients are in parentheses.

The SUR coefficients in Table 2 are estimated from different samples. Model 1 is estimated from a sample that excludes China, model 2 from a sample that excludes South Korea, and model 3 from a sample that excludes both in order to address earlier concerns about these two countries being responsible for all but one of the extreme values in the descriptive statistics of the common sample. A comparison of 1 and 3 shows very negligible differences between their estimates but an increase in the adjusted R^2 of almost 3% when South Korea is excluded from the sample along with China. However, the standard errors are smaller for the estimates of 1 thereby suggesting that including South Korea in the sample contributes something, however little, to the estimation procedure. An examination of model 4 shows estimates and standard errors very comparable to that of model 2 suggesting very little differences would result had I chose to discard either South Korea or Pakistan from the sample. Recall that model 4 was run to address the concerns over using forecasted observations in the dataset.

Based on a comparison of these results and that of the full sample set, it was decided to include all of the countries available in order to incorporate as much information as possible into the estimation procedure to enable efficiency. Furthermore, the countries in question were all major participants in the Green Revolution experiments and thus, based on that information alone should not be excluded from the sample.

V CONCLUSION

In attempting to investigate the significance of agriculture's contribution to economic growth, factor transfer effects from a positive agricultural productivity shock – via the Green Revolution - were examined for a long and narrow panel of Asian and South-East Asian counties for the period of 1961-1989. SUR estimates indicate that while both factor transfer variables, DKS and DLS, are individually and jointly significant, only DKS had the desired effect. According to this study, a 1% increase in the transfer of capital rate is expected to contribute, albeit by a small amount, to annual national income growth while a 1% increase to labour transfer rate is expected to actually contribute negatively to economic growth. This counterintuitive result suggests failure on the part of the theory. However, it is the belief of this author that this is more indicative of the poor quality of the productivity shock. Research into the literature documents many design flaws in the technologies that made the initial gains unsustainable in the long run. Future tests of the theory should be centred on agricultural productivity shocks that promote quality as well as quantity.

APPENDICES

1.1 Derivation of the Model

This section is taken from Sherman Robinson's *Sources of Growth in Less Developed Countries: A Cross Section Study* (1971).

Let: D denote the time derivative or time difference

R denote rate of growth

A simple dynamic model is derived from a general aggregate production function:

$$Y = F(K,L)$$

$$DY = (\partial F/\partial K)\ DK + (\partial F/\partial L)\ DL$$

$$DY/Y = (\partial F/\partial K)\ DK/Y + (\partial F/\partial L)\ DL/Y$$

Multiplying by L/L and rearranging yields

$$DY/Y = (\partial F/\partial K)\ DK/Y + [(\partial F/\partial L)\ L]/Y\ DL/L$$

$$RY = (\partial F/\partial K)\ DK/Y + [(\partial F/\partial L)\ L]/Y\ RL \tag{1}$$

$$RY = \beta_1\ RINV + \beta_2\ RL \tag{2}$$

where RINV = DK/Y = the investment rate

In order to incorporate the effect of structural change on growth, a more complex two-factor, two-sector growth model is developed.

The economy is divided into two sectors - an industrialized manufacturing sector and a relatively backward agricultural sector.

There are only two factors of production – labour and capital – which are initially distributed between the two sectors. The supply of each factor in each sector grows at some natural exponential rate due to population growth and investment. Because it is assumed that the factors are perfectly mobile between the sectors, the rates of growth in both sectors can change.

$$Y = P_A A + P_M M \tag{3}$$

where P_A denotes the price of the agricultural good

A denotes the agricultural good

P_M denotes the price of the manufactured good

M denotes the manufactured good

Let $a = P_A A/Y$ = share of sector A in total output

$m = P_M M/Y$ = share of sector M in total output

$$Y = a\,A + m\,M$$

$$DY = a\,DA + m\,M$$

$$DY/Y = a\,DA/A + m\,M/M$$

(4) $$RY = a\,RA + m\,RM$$

Let the production functions for each sector be specified as $A = A\,(K_A + L_A)$ and $M = M\,(K_M + L_M)$.

$$DA = (\partial A/\partial K_A)\,DK_A + (\partial A/\partial L_A)\,DL_A$$

(5) $$DA = MPK_A\,DK_A + MPL_A\,DL_A$$

(6) $$DM = MPK_M\,DK_M + MPL_M\,DL_M$$

where MPK_A , MPK_L , MPL_A , MPL_K , are the marginal physical products of the inputs in the two sectors.

On the assumption that inputs are transferred from the relatively backward sector, A, to the more advanced sector, M:

(7) $DK_A = RK_A K_A - T_K K$

(8) $DL_A = RL_A L_A - T_L L$

(9) $DK_M = RK_M K_M + T_K K$

(10) $DL_M = RL_M L_M + T_L L$

where T_K, and T_L are the rates of input transfer between sectors.

Substituting (7) and (8) into (5) yields

(11) $DA = MPK_A K_A \; RK_A - MPK_A K T_K + MPL_A L_A \; RL_A - MPL_A L T_L$

If there were no factor mobility, then $T_K = T_L = 0$ and so

(12) $RA^* = (MPK_A K_A RK_A + MPL_A L_A RL_A)/A$

Substituting (12) into (11)

$$(13)\quad RA = RA^* + (MPK_A\, K\, T_K + MPL_A\, L\, T_L)/A$$

A similar expression is derived for RM. Substituting both into (4) will yield an expression

$$(14)\quad RY = RY^* + (P_M\, MPK_M - P_A\, MPK_A)\, T_K\, K/Y + (P_M\, MPL_M - P_A\, MPL_A)\, T_L\, L/Y$$

where $RY^* = a\, RA^* + m\, RM^*$

Notice that in the above equation, the second and third terms reflect the contribution of factor transfers from the relatively less to the more productive sector. The differences in the value of the marginal products for labour and capital between the two sectors are a function of technological factors, which are reflected in the relative prices of the outputs. Thus, the output effect is embodied in the coefficient estimates of the factor transfer variables.

Equation (14) can be viewed as a counterfactual; the growth rate of the economy is dependent on the natural growth rate of its inputs and the contribution of factor reallocation when there is a technological or demand shock.

Unfortunately, equation (14) cannot be estimated as is. It must be reformulated so that the variables are defined in terms of measurable quantities.

First we consider the rates of transfer variables, T_K and T_L:

Treating labour first, we define

(15) $L = L_A + L_M$

(16) $SL_A = L_A/L$ = share of labour force in sector A

(17) $SL_M = L_M/L$ = share of labour force in sector M

and so

(18) $SL_A + SL_M = 1$

Note: $DL = DL_A + DL_M$

Taking the derivative of (17)

$$DSL_M = (L\ DL_M - L_M\ DL)/L^2$$

$$= L/L^2\ (DL_M) - (L_M\ DL)/L^2$$

and substituting in (10) for DL_M

$$= L\,(RL_M\,L_M + T_L\,L) - (L_M\,DL)/L^2$$

$$= RL_M\,(L_M/L) + T_L - (L_M/L)\,(DL/L)$$

$$DSL_M = RL_M\,SL_M + T_L - SL_M\,(DL/L)$$

Recalling that $DL = DL_A + DL_M$

$$DL/L = SL_A\,RL_A + SL_M\,RL_M$$

So $DSL_M = RL_M\,SL_M + T_L - SL_M\,(SL_A\,RL_A + SL_M\,RL_M)$

$$= T_L + RL_M\,SL_M - SL_M\,SL_A\,RL_A + SL_M\,SL_M\,RL_M$$

$$= T_L + RL_M\,SL_M - RL_M\,SL_M\,SL_M - SL_M\,SL_A\,RL_A$$

$$= T_L + RL_M\,SL_M(1-SL_M) - SL_M\,SL_A\,RL_A$$

$$= T_L + RL_M\,SL_M(SL_A) - SL_M\,SL_A\,RL_A$$

(19) $DSL_M = T_L + (RL_M - RL_A)\,SL_M\,SL_A$

Since the shares, SL_M and SL_A, are each less than one, and in general, the difference in the natural rates of growth are very small or zero, then the second term in equation (19) will be very small or zero thus,

(20) $DSL_M = T_L$

The above equation states that the rate of transfer of labour can be measured by estimating the change over time of the labour share in the advanced sector. An equivalent formula can be derived for T_K.

However, even with the rates of transfer defined in terms of measurable quantities, equation (14) is not yet in suitable form.

We must now consider the contribution of labour transfers to the rate of growth:

(21) $(P_M\, MPL_M - P_A\, MPL_A)\, T_L\, L/Y$

Defining the average wage of labour, W_L, such that the total payments to labour out of national income (wage bill) are $W_L\, L = W_{LM}\, L_M + W_{LA}\, L_A$

(22) $W_L\, L = W_{LM}\, SL_M + W_{LA}\, SL_A$

Assume that labour is paid the value of its marginal product. Then, equation (21) becomes:

$$(23) \quad [(W_{LM} - W_{LA})/W_L]\ T_L\ [W_L L/Y]$$

Thus the contribution of labour transfer to the rate of growth can be represented by the above equation. Both the wage bill, $[W_L\ L/Y]$, and the transfer rate, T_L, are estimable. The first term in parenthesis represents the spread in productivity between sectors, measured in wage units. The fact that it has been transformed into a ratio (diving by Y) allows cross country comparisons without the need of exchange rates.

An analogous term can be derived for capital, replacing every L with K.

This term will be constant across countries if T_L and T_K respond quickly to any sectoral productivity differences. The term is expected to be relatively constant because it is measured in average wage units that dampen wide variations.

Equation (23) and the analogous term for capital mobility can now be used in the dynamic model to create an equation suitable for estimation by regression analysis.

Combining equations (2) with (14) and (23) yields

$$(24) \quad RY = \beta_0 + \beta_1\ RINV + \beta_2\ RL + \beta_3\ T_K\ (r_K\ K/Y) + \beta_4\ T_L\ (W_L\ L/Y)$$

where r_K = average rental rate on capital

W_L = average wage of labour

$(r_K K/Y)$ = capital share of total income

$(W_L L/Y)$ = labour share of total income

T_K = transfer rate of capital

T_L = transfer rate of labour

$\beta_3 = (r_M - r_A)/r_K$ = % difference in rental rate between sectors

$\beta_4 = (W_M - W_A)/W_L$ = % difference in wages between sectors

Because sector M is more productive than sector A, we can interpret the last two terms as changes in the manufacturing share of total income as a result of the factor transfer effect.

Due to data limitations, DKS will proxy for T_K $(r_K K/Y)$ and DLS will proxy for T_L $(W_L L/Y)$. Thus, the model estimated is

$$RY_i == \beta_0 + \beta_1 RINV_i + \beta_2 RL_i + \beta_3 DKS_i + \beta_4 DLS_i$$

DKS is the annual change in the manufacturing share of total GDP.

It was derived indirectly. The agricultural share of total income was retrieved from WDI and the annual change calculated for the period of study (1961-89). Then these values were subtracted from 1 to get the annual change in manufacturing share of total income.

DLS was created by calculating the annual change in the urbanization rate for the period of study.

1.2 Estimation Results

SUR1

```
Dependent Variable: ?RY
Method: Seemingly Unrelated Regression
Sample: 1961 1989
Included observations: 29
Number of cross-sections used: 11
Total panel (balanced) observations: 319
==========================================================================
     Variable        Coefficient   Std. Error    t-Statistic     Prob.
==========================================================================
        C            2.152280      0.329925      6.523550      0.0000
      ?RINV          0.126962      0.008370      15.16864      0.0000
       ?RL           1.023302      0.137364      7.449555      0.0000
==========================================================================
 Weighted Statistics
==========================================================================
Log likelihood      -768.5112
==========================================================================
 Unweighted Statistics
==========================================================================
R-squared            0.361432    Mean dependent var         5.780002
Adjusted R-squared   0.357390    S.D. dependent var         4.288860
S.E. of regression   3.438076    Sum squared resid          3735.236
Durbin-Watson stat   1.522063
==========================================================================
```

SUR2

```
Dependent Variable: ?RY
Method: Seemingly Unrelated Regression
Sample: 1961 1989
Included observations: 29
Number of cross-sections used: 11
Total panel (balanced) observations: 319
==========================================================================
     Variable        Coefficient   Std. Error    t-Statistic     Prob.
==========================================================================
        C            3.361136      0.392861      8.555533      0.0000
      ?RINV          0.122426      0.008382      14.60561      0.0000
       ?RL           1.072819      0.156475      6.856187      0.0000
      ?DKS           0.156644      0.041518      3.772926      0.0002
      ?DLS          -0.349102      0.085810     -4.068299      0.0001
==========================================================================
 Weighted Statistics
==========================================================================
Log likelihood      -762.0764
==========================================================================
 Unweighted Statistics
==========================================================================
R-squared            0.414581    Mean dependent var         5.780002
Adjusted R-squared   0.407123    S.D. dependent var         4.288860
S.E. of regression   3.302357    Sum squared resid          3424.346
Durbin-Watson stat   1.584514
==========================================================================
```

Excluding China

```
Dependent Variable: ?RY
Method: Seemingly Unrelated Regression
Sample: 1961 1989
Included observations: 29
Number of cross-sections used: 10
Total panel (balanced) observations: 290
======================================================================
      Variable       Coefficient   Std. Error   t-Statistic     Prob.
======================================================================
         C            4.185959     0.491722     8.512864      0.0000
       ?RINV          0.103592     0.008914     11.62083      0.0000
        ?RL           0.918534     0.182748     5.026245      0.0000
       ?DKS           0.113775     0.042318     2.688549      0.0076
       ?DLS          -0.404484     0.115941    -3.488710      0.0006
======================================================================
  Weighted Statistics
======================================================================
Log likelihood       -687.4247
======================================================================
Unweighted Statistics
======================================================================
R-squared             0.290205   Mean dependent var    5.741332
Adjusted R-squared    0.280243   S.D. dependent var    3.635249
S.E. of regression    3.084091   Sum squared resid     2710.811
Durbin-Watson stat    1.639461
======================================================================
```

Excluding South Korea

```
Dependent Variable: ?RY
Method: Seemingly Unrelated Regression
Sample: 1961 1989
Included observations: 29
Number of cross-sections used: 10
Total panel (balanced) observations: 290
======================================================================
      Variable       Coefficient   Std. Error   t-Statistic     Prob.
======================================================================
         C            3.119059     0.452509     6.892812      0.0000
       ?RINV          0.131044     0.009317     14.06568      0.0000
        ?RL           1.114026     0.167073     6.667881      0.0000
       ?DKS           0.178156     0.047613     3.741738      0.0002
        ?DL          -0.355120     0.093920    -3.781086      0.0002
======================================================================
  Weighted Statistics
======================================================================
Log likelihood       -690.8194
======================================================================
Unweighted Statistics
======================================================================
R-squared             0.446085   Mean dependent var    5.528341
Adjusted R-squared    0.438311   S.D. dependent var    4.280198
S.E. of regression    3.207833   Sum squared resid     2932.704
Durbin-Watson stat    1.686746
======================================================================
```

Excluding China and South Korea

```
Dependent Variable: ?RY
Method: Seemingly Unrelated Regression
Sample: 1961 1989
Included observations: 29
Number of cross-sections used: 9
Total panel (balanced) observations: 261
=========================================================================
       Variable        Coefficient    Std. Error    t-Statistic     Prob.
=========================================================================
          C              4.078972      0.527459      7.733249      0.0000
        ?RINV            0.111192      0.009875      11.25940      0.0000
         ?RL             0.999677      0.185851      5.378920      0.0000
        ?DKS             0.125049      0.048444      2.581290      0.0104
         ?DL            -0.476056      0.124619     -3.820100      0.0002
=========================================================================
 Weighted Statistics
=========================================================================
Log likelihood          -613.2196
=========================================================================
Unweighted Statistics
=========================================================================
R-squared                0.307736    Mean dependent var        5.457412
Adjusted R-squared       0.296919    S.D. dependent var        3.538741
S.E. of regression       2.967232    Sum squared resid         2253.943
Durbin-Watson stat       1.768362
=========================================================================
```

Excluding Pakistan

```
Dependent Variable: ?RY
Method: Seemingly Unrelated Regression
Sample: 1961 1989
Included observations: 29
Number of cross-sections used: 10
Total panel (balanced) observations: 290
=========================================================================
       Variable        Coefficient    Std. Error    t-Statistic     Prob.
=========================================================================
          C              3.506548      0.440271      7.964530      0.0000
        ?RINV            0.133210      0.009202      14.47644      0.0000
         ?RL             1.127336      0.178819      6.304341      0.0000
        ?DKS             0.156347      0.044808      3.489299      0.0006
         ?DL            -0.433242      0.092557     -4.680818      0.0000
=========================================================================
 Weighted Statistics
=========================================================================
Log likelihood          -699.7620
=========================================================================
Unweighted Statistics
=========================================================================
R-squared                0.433361    Mean dependent var        5.743899
Adjusted R-squared       0.425408    S.D. dependent var        4.429961
S.E. of regression       3.357991    Sum squared resid         3213.690
Durbin-Watson stat       1.647909
=========================================================================
```

1.3 TESTS

Forecasting missing observations:

Pakistan – missing RINV observations for 1982 and 1983

Using all explanatory variables, regress RINV on RL, DKS, and DLS

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.491916
R Square	0.241981
Adjusted R Square	0.108213
Standard Error	15.39915
Observations	21

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	3	1286.898	428.966	1.808961	0.183752
Residual	17	4031.276	237.1339		
Total	20	5318.174			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	-103.124	97.77669	-1.05469	0.306326	-309.415	103.1667	-309.415	103.1667
RL	-21.5559	10.08776	-2.13684	0.047442	-42.8393	-0.2726	-42.8393	-0.2726
DKS	-2.04745	1.662604	-1.23147	0.23491	-5.55525	1.460338	-5.55525	1.460338
DLS	41.19374	28.34965	1.45306	0.164417	-18.6189	101.0064	-18.6189	101.0064

RINV82=-103.124-21.25559*RL82-2.04745*DKS82+41.19374*DLS82

=-103.124-21.25559*3.24 -2.04745*(-1.07)+41.19374*3.90

=-10.1188

RINV83=-103.124-21.25559*RL83-2.04745*DKS83+41.19374*DLS83

=-103.124-21.25559*3.27 -2.04745*1.09+41.19374*3.88

=-16.0118

-Chow Test for Pooling-

Unrestricted:

```
Dependent Variable: ?RY
Method: Pooled Least Squares
Sample: 1961 1989
Included observations: 29
Number of cross-sections used: 11
Total panel (balanced) observations: 319
White Heteroskedasticity-Consistent Standard Errors & Covariance
===============================================================
      Variable        Coefficient   Std. Error   t-Statistic   Prob.
===============================================================
    _1--_1RINV         0.163844     0.039431     4.155260     0.0000
    _2--_2RINV         0.164813     0.028980     5.687125     0.0000
    _3--_3RINV         0.360095     0.051362     7.010849     0.0000
    _4--_4RINV         0.060730     0.027910     2.175945     0.0304
    _5--_5RINV         0.147084     0.036430     4.037445     0.0001
    _6--_6RINV         0.205031     0.032438     6.320808     0.0000
    _7--_7RINV         0.145822     0.022374     6.517469     0.0000
    _8--_8RINV         0.061348     0.041559     1.476176     0.1411
    _9--_9RINV         0.158061     0.066313     2.383540     0.0179
   _10--_10RINV        0.042189     0.025581     1.649227     0.1003
   _11--_11RINV        0.009312     0.024918     0.373701     0.7089
     _1--_1RL          1.819814     1.346846     1.351167     0.1778
     _2--_2RL         -1.594491     1.236162    -1.289873     0.1982
     _3--_3RL          0.176195     0.563376     0.312749     0.7547
     _4--_4RL         -2.548622     1.087534    -2.343487     0.0198
     _5--_5RL          1.285948     0.993058     1.294937     0.1965
     _6--_6RL          3.444163     1.837747     1.874122     0.0620
     _7--_7RL         -3.710805     2.038307    -1.820533     0.0698
     _8--_8RL         -1.037566     1.299694    -0.798316     0.4254
     _9--_9RL          1.251965     1.405953     0.890474     0.3740
    _10--_10RL        -0.285603     0.721307    -0.395953     0.6925
    _11--_11RL         0.864481     1.194182     0.723911     0.4698
     _1--_1DKS         0.735219     0.259680     2.831256     0.0050
     _2--_2DKS        -0.063261     0.072469    -0.872938     0.3835
     _3--_3DKS         0.657600     0.461750     1.424146     0.1556
     _4--_4DKS        -0.018873     0.129340    -0.145918     0.8841
     _5--_5DKS        -0.040187     0.238938    -0.168190     0.8666
     _6--_6DKS         0.146897     0.275552     0.533103     0.5944
     _7--_7DKS         0.195211     0.179562     1.087154     0.2780
     _8--_8DKS         0.408522     0.214319     1.906140     0.0577
     _9--_9DKS        -0.394207     0.242450    -1.625933     0.1052
    _10--_10DKS       -0.024338     0.183594    -0.132565     0.8946
    _11--_11DKS        0.007857     0.138943     0.056551     0.9549
     _1--_1DLS         0.164902     0.292833     0.563128     0.5738
     _2--_2DLS         2.337995     0.651554     3.588337     0.0004
     _3--_3DLS         0.897700     0.452962     1.981845     0.0485
     _4--_4DLS         0.928191     0.737736     1.258162     0.2094
     _5--_5DLS         1.135082     0.826620     1.373160     0.1709
     _6--_6DLS        -1.962656     0.393231    -4.991097     0.0000
     _7--_7DLS         0.956475     0.649364     1.472941     0.1420
     _8--_8DLS        -0.762847     0.537028    -1.420499     0.1566
     _9--_9DLS        -2.058487     1.852195    -1.111377     0.2674
```

```
   _10--_10DLS        -5.501770    2.196979   -2.504244     0.0129
   _11--_11DLS        -0.039205    0.265016   -0.147935     0.8825
   Fixed Effects
        _1--C         -0.132102
        _2--C         -3.035182
        _3--C          1.496830
        _4--C          9.295103
        _5--C         -4.181067
        _6--C          2.653047
        _7--C         12.39546
        _8--C          9.843629
        _9--C          8.478872
       _10--C         29.22007
       _11--C          2.701049
====================================================================
R-squared              0.667006    Mean dependent var      5.780002
Adjusted R-squared     0.598894    S.D. dependent var      4.288860
S.E. of regression     2.716262    Sum squared resid       1947.813
Log likelihood        -741.2202    F-statistic             12.29784
Durbin-Watson stat     1.931474    Prob(F-statistic)       0.000000
====================================================================
```

Restricted:

```
Dependent Variable: ?RY
Method: Pooled Least Squares
Sample: 1961 1989
Included observations: 29
Number of cross-sections used: 11
Total panel (balanced) observations: 319
White Heteroskedasticity-Consistent Standard Errors & Covariance
====================================================================
      Variable         Coefficient  Std. Error   t-Statistic   Prob.
====================================================================
          C             3.114135    0.611819     5.089966     0.0000
        ?RINV           0.122891    0.019302     6.366863     0.0000
         ?RL            1.243794    0.341326     3.644004     0.0003
        ?DKS            0.204909    0.079390     2.581025     0.0103
        ?DLS           -0.358580    0.174656    -2.053065     0.0409
====================================================================
R-squared              0.418355    Mean dependent var      5.780002
Adjusted R-squared     0.410946    S.D. dependent var      4.288860
S.E. of regression     3.291694    Sum squared resid       3402.269
Log likelihood        -830.1790    F-statistic             56.46209
Durbin-Watson stat     1.622281    Prob(F-statistic)       0.000000
====================================================================
```

Null: intercept and slope coefficients are the same across the cross-sections (countries)

Alt: intercept and slope coefficients are not the same across

F=[(3402.269-1947.813)/5]/[1947.813/(319-5*11)]=39.42641

$F^{5}_{55,\,0.05} \approx 2.37$

Reject null at 5% significance level, thus should not pool data and estimate by OLS.

-LM test for Contemporaneous Correlation-

Null: The error terms are not contemporaneously correlated across regressions.

Alt: The error terms are contemporaneously correlated across regressions.

$\Sigma^{n}_{i=2}\,\Sigma^{i-1}_{j=1}\,r_{ij}^{2} = 3.447395$ (computed from the residual correlation matrix)

$LM_{stat} = T\,\Sigma^{n}_{i=2}\,\Sigma^{i-1}_{j=1}\,r_{ij}^{2} = 29*3.447395 = 99.97445$
Chi-square with df=55 @ 5% significance = 73.29335

Thus, reject null of zero contemporaneous correlation between the errors across equations.

-Wald Test-

Factor growth coefficients

```
Wald Test:
Equation: POOL01
Null Hypothesis:  C(2)=0
                  C(3)=0
F-statistic        147.2947     Probability      0.000000
Chi-square         294.5894     Probability      0.000000
```

Factor transfer coefficients:

```
Wald Test:
Equation: POOL01
Null Hypothesis:  C(4)=0
                  C(5)=0
F-statistic        15.81769     Probability      0.000000
Chi-square         31.63537     Probability      0.000000
```

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