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The Effect of Conflict and Economic Shocks on Development

DISSERTATION

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by

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For those still sitting under the shadow, and reality, of conflict.

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Abstract of the Dissertation

The Effect of Conflict and Economic Shocks on Development

By

Nathan Fiala

Doctor of Philosophy in Economics

University of California, Irvine, 2009

Professor Stergios Skaperdas, Chair

The effect of defense spending and the environment on economic growth remains an open question in the development literature. In order to better understand the impact of these on development, this dissertation looks first at the effect of defense spending on an economy, and then at the effects of an environmental change on an economy. First, using a Vector Error Correction model and accounting for the double-counting of past investment in durable military goods, how disaggregated elements of defense spending affect economic growth in the U.S. from 1976 to 2007 is explored. In the short-run, only defense consumption is statistically significant and positively affects the economy with a slightly larger effect than federal government expenditures. In the long-run, defense equipment and software retards growth, while defense consumption and investment in structures promotes it. Then, how security spending can depend on institutions, such as property rights and social norms is explored using a model of negotiated peace. New gross domestic production values and growth rates without security activities are constructed for 134 countries for the years 1991 to 2005 to identify

the effect of including these activities in *GDP* and the potential production loss from security spending beyond a "minimum level" is calculated. In order to explore environmental effects, the lagged first and second order effects of rainfall shocks for a balanced data set of 110 countries from 1982 to 1999 are explored, along with differential effects by region and GDP components. Finally, the effect of property rights institutions for improving the ability of farmers to prepare for shocks is explored.

Chapter 1

All Expenditures are not the Same: The Effects of Disaggregated Defense Spending on Economic Growth in the United States

1.1 Introduction

There is not currently a consensus regarding the economic implications of defense spending in development and defense literature. A number of studies have found defense outlays have a positive effect on GDP growth (e.g. Benoit (1972 and 1978) and Atesoglu (2002)), while a number have also found a negative or zero effect (e.g. Deger and Smith (1983), Biswas and Ram (1986), and Dunne et al. (2005)). In a comprehensive review of the growth effects of defense expenditure, Ram (1995) summarizes 35 years of contradictory empirical evidence based on cross-sectional studies, raising concerns regarding the assumption of system homogeneity.

This is a well-founded concern: military expenditure is composed of two main categories, investment and consumption. Consumption includes expenditure on intermediate goods, personnel compensation, and services. Investment includes investment in equipment and software as well as investment in military structures. There is no *a priori* reason to believe that the effect of these two categories are equal on an economy. It would seem reasonable to suppose, for example, that a dollar paid to military personnel would have a different effect than a dollar spent on research and development. Thus, for a given level of military spending, variation in the composition of that spending should generate fluctuations in aggregate output.

Abstracting from the potential problem of aggregating the various components of military outlays for a given economy, consider also a very popular form of defense/growth studies: cross-country regression. If the effects of defense expenditure differ across economies, then pooling different proxy variables, time periods, and country groups yields significantly different empirical results, as Ram (1995) documents.

The effect of U.S. defense spending has been studied by a number of researchers using aggregate data with similarly contradictory results. Atesoglu and Mueller (1990) find a small positive significant effect of defense spending on growth. Huang and Mintz (1991) use the flexible accelerator investment model and find that defense spending lowered investment and, therefore, growth. Ward and Davis (1992) find a positive externality of defense spending but a net negative effect on growth. More recently, Atesoglu (2002), Mehanna (2004), and Smith and Tuttle (2006) use Vector Error Correction models (VECMs) to account for endogeneity concerns and still find contradictory results. Atesoglu finds a small positive impact of defense spending, while Mehanna finds no effect. Smith and Tuttle re-examine the data from Atesoglu and find there is no effect of defense outlays when controlling for U.S. military involvement. All of these authors keep defense expenditures as an aggregate outlay.

There is an additional general issue with previous studies' data. In U.S. accounting methods, and presumably accounting methods of most countries, defense expenses include depreciated capital from previous years' spending. This means that defense expenditure does not necessarily reflect actual expenditure but also includes depreciated rates of previous years' expenditure. This double counting can then lead to spurious findings regarding the effect on contemporaneous spending.

In order to test the hypothesis that the marginal effects of defense outlays on aggregate income are equal, we use a VECM on disaggregated data in the U.S. from 1976 to 2007 without depreciation accounting to estimate the defense expenditure growth effects of each component and compare this to two different government expenditures: federal and local. The results suggest that the marginal effects of defense outlays do differ significantly by category. We find that in the short-run, only defense consumption is statistically significant and positively affects the economy with a slightly larger effect than federal government expenditures. In the long-run, defense equipment and software retards growth, while defense consumption and investment in structures promotes it. This leads us to conclude that aggregating variables with both different quantitative and qualitative effects is problematic.

The remainder of this paper is organized as follows: section 2 motivates the issue of aggregation using a short disaggregated model of defense spending; section 3 presents the empirical estimation, including the data, empirical model, and results of the VECM estimation; section 4 then concludes the discussion.

1.2 Disaggregate Model Of Defense Spending

Theoretically, the effect of defense spending on an economy can be either positive or negative, or perhaps even both. As Dunne et al. (2004) and Dunne (1996) discuss in detail, defense spending can stimulate demand, or it may create budgetary pressure that can hurt an economy. Which of these effects is most important for an economy is therefore an empirical question.

This of course suggests that the different outlays in defense spending, such as military consumption, military structures, and equipment and software spending, may have different supply and demand side effects. In the short-run, some crowding out of investment may retard the economy; however, in the long-run, the effects of positive spillover of military technology research and development into the civil sector may be positive.

For instance, equipment and software expenditure may create positive long-run effects through technology spillovers. Technology may take a long time to be developed and applied, but its effect increases in time. Equipment and software expenditure (i.e. spending on tanks and other equipment) does not have a direct social benefit, and so can be thought of as a waste of resources from a welfare perspective (e.g. Fiala (2008) and Nordhaus (2005)).

However, military structures, like bases, may stimulate local economies. In the short-run, their demand side effects may be positive when opening, or negative when closing, perhaps even at different rates of effect. Civilian labor hired in construction and businesses forming around the bases may benefit. In the long-run, the effects may still be positive if military consumption is viewed as simple fiscal stimulus. Composed mainly of personnel pay, we would expect it to have positive demand side effects through consumption spending. Theory suggests though that these positive effects may be offset by the forgone production of civilian production.

It is not clear then what the long- or short-run effects of this consumption may be. Additionally, composition of defense spending has changed over the years. Figure 1 shows the changes in the composition of total defense spending from 1973 to 2007. Defense structures outlays as a percent of total spending have stayed similar over time, while equipment and software has changed over time. As this composition has changed, so would we expect to find different effects of aggregate data over different time periods. Luckily, U.S. data allows us to disaggregate defense expenditures easily.

1.3 Empirical Estimation

1.3.1 Data

We collected GDP and defense expenditure data in billions of real 2000 dollars from the seasonally adjusted Bureau of Economic Analysis data. The series, from 1973 to 2007, is from NIPA tables 1.1.5, 3.9.3, 3.11.4, and 3.11.5. Yearly nominal data is used as appropriation is done annually. Also, annual is preferred because of our interest in the long-run effect of disaggregate expenditures.

In BEA accounting, defense expenditure on equipment and software is recorded as investment, then discounted as consumption for years to come. Using the NIPA table 3.11.5, we adjusted for this intertemporal relation by subtracting durable goods from military consumption. This allows us to observe the effects of the expenditure as it happens. Otherwise, the effects of military consumption is double counted and will partly reflect changes in economic accounting and not expenditure. As we do not know the accounting rates or schedule, simply subtracting out durables is the most accurate method to use.

The data then consists of civilian GDP (GDP without defense expenditure), civilian federal government expenditures, state and local expenditures, defense consumption, equipment and software expenditures and defense structures. All data is logged. The VECM automatically differences the data, so the results are interpretable as percent change.

A Dickey Fuller test fails to reject the existence of unit roots in the levels of all the variables. The Durbin-Watson test rejects serial correlation in the data, so there no need to use the augmented Dickey Fuller test. All variables have a unit root except defense consumption, which is differenced in order to obtain a unit root, giving a final time period of 1976 to 2007.

Table 1 shows the results of Johansen's co-integration test (Johansen 1991) for these variables using *Eviews*, version 6 for the model described in the next section. At the 0.05 significance level, the tests fail to reject that are at most 3 co-integrated relations and suggest that all the series are co-integrated of the second degree.

1.3.2 Methodology

Estimation of the economic effects of defense spending can be difficult. There are many reasons to doubt the assumption of exogeneity of aggregate macro-economic variables, especially defense spending. For example, Garfinkel (1990), provides theoretical reasons that suggests reverse causation from economic growth to defense expenditure as fluctuations in military spending can be an endogenous result of fluctuations in aggregate economic activity.

Another source of possible endogeneity is policy. For instance, if a government uses war to stimulate a stagnant economy, then the exogeneity assumption of defense outlays is called into question by reversing the direction of causality between defense and growth. Testing United States data since 1897, Hess and Orphanides (1992) find that the probability of war initiation increases over 60 percent when the economy is doing poorly and the president is up for re-election.

To overcome this difficulty, we adopt a simultaneous equations approach. Generally, treating macro-economic variables as endogenous is a more robust approach. Since the budgeting is done a year in advance, spending is a function of lagged output. However, deficits are possible, and spending could be based on the expectation of next year's output. This interrelation forces us to include all these variables in one system and suggests a two-year lag period for the empirical model.

The data and theoretical issues therefore suggest using a VECM[1] with second

[1]This model is now very common in the literature, and so we refrain from a complete exposition of it. For a fuller description, see Atesoglu (2002).

order lags of the following form:

$$\Delta y_t = c + [\Gamma_1 \Gamma_2 \prod][\Delta y_{t-1} \Delta y_{t-2} y_t]^T + \epsilon_t \tag{1.1}$$

where y is a vector composed of civilian GDP, local and state expenditures, equipment and software expenditure, military structures expenditure, and military consumption expenditure. We assume that the error ϵ is white noise.

With one co-integration relation, the model is:

$$\Delta y_t = c + \sum_{i=1}^{2} \alpha_i \Delta y_{t-i} + \alpha_i \beta' y_t + \epsilon_i \tag{1.2}$$

where $\alpha_i \beta'$ is a stationary combination of the components of y, also known as the error correction equation.

1.3.3 Results

Table 2 presents the results of the co-integration equation. This equation is often interpreted as the long-run relationship of the variables and is consistent with the results of the VECM in Table 3. Note that the co-integration equation is solved for the error correction term, and so the signs on the co-integration coefficients are the opposite of their estimated sign.

In Table 2, defense equipment and software obtain a statistically significant negative sign, and so can be interpreted as retarding civilian GDP growth. Defense consumption and investment in structures on the other hand have statistically significant positive signs and so promote civilian GDP growth. These two effects though have very different magnitude effects.

In Table 4, only defense consumption and federal government expenditures at t-2 are statistically significant for civilian GDP growth. The remaining variables do not show a statistical significance. In comparison to federal government expenditures, defense consumption has a larger effect, of approximately 50% magnitude.

The adjusted R squared of GDP growth in the VECM specification suggests that the model specification and fit is adequate. As there is a constraint of data, we have also explored a larger dataset of defense spending going back to 1929, which we omit here. The larger data set, which includes additional lags, taxes, deficits, inflation, or war time dummies, does not significantly change the quantitative results where some defense outlays are significant and others are not.

Figure 3 presents the generalized impulse response functions for each variable from Table 4. No variables are significantly above zero and only state and local government expenditures has a lasting effect, while the response for the remaining variables appears to die out quickly over time.

1.4 Conclusion

This paper suggests a caution to researchers using aggregated defense spending. Our central hypothesis, that growth in military spending affects equipment and software, military structures, and military consumption differently in the short-run requires that any of the coefficients on these three items be different. We have found that the effect of defense outlays differs in growth effects by type. Its effects are negative for some outlays and positive for others. There is also the concern of accounting methods where defense expenditure does not necessarily reflect actual expenditure but also includes depreciated capital.

The results also suggest that pooling together different countries with different aggregate defense composition into single datasets can make matters worse as pooling assumes the marginal effect of spending is similar across countries. In addition, the composition of defense expenditure is likely to change annually.

This variance in composition of defense expenditure across countries and over time may help explain the contradictory results often obtained by cross-sectional studies.

Though it is tempting to run regressions using aggregate data, before more aggregate models of defense spending are run, more work must be done to understand the serious implications of such aggregation and the accounting methods used to construct the data.

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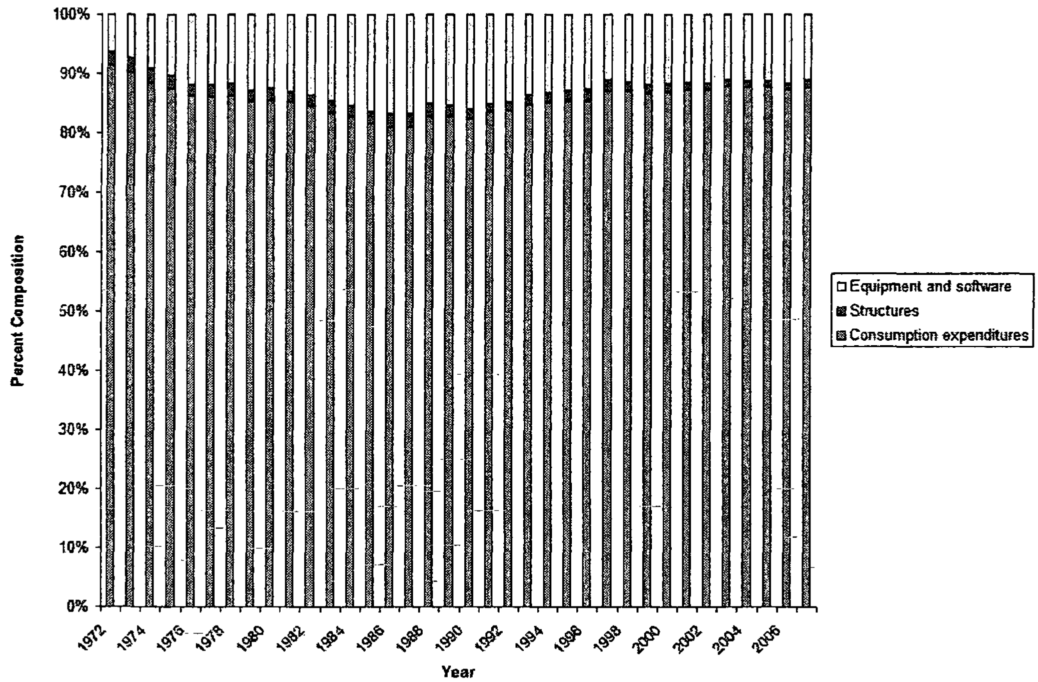

Fig. 1.1: Composition of defense expenditures from 1972 to 2007.

Table 1.1: Johansen Co-integration Test

Hypothesized Number of Co-integration Relations	Eigenvalue	Trace Statistic	Critical Value	Prob
None	0.685033	99.20185	60.06141	0
At most 1	0.612805	61.07732	40.17493	0.0001
At most 2	0.444873	29.76606	24.27596	0.0092
At most 3	0.26243	10.34362	12.3209	0.1049
At most 4	0.009008	0.298595	4.129906	0.6462

[1]Test denotes rejection of the hypothesis at the 0.05 level.

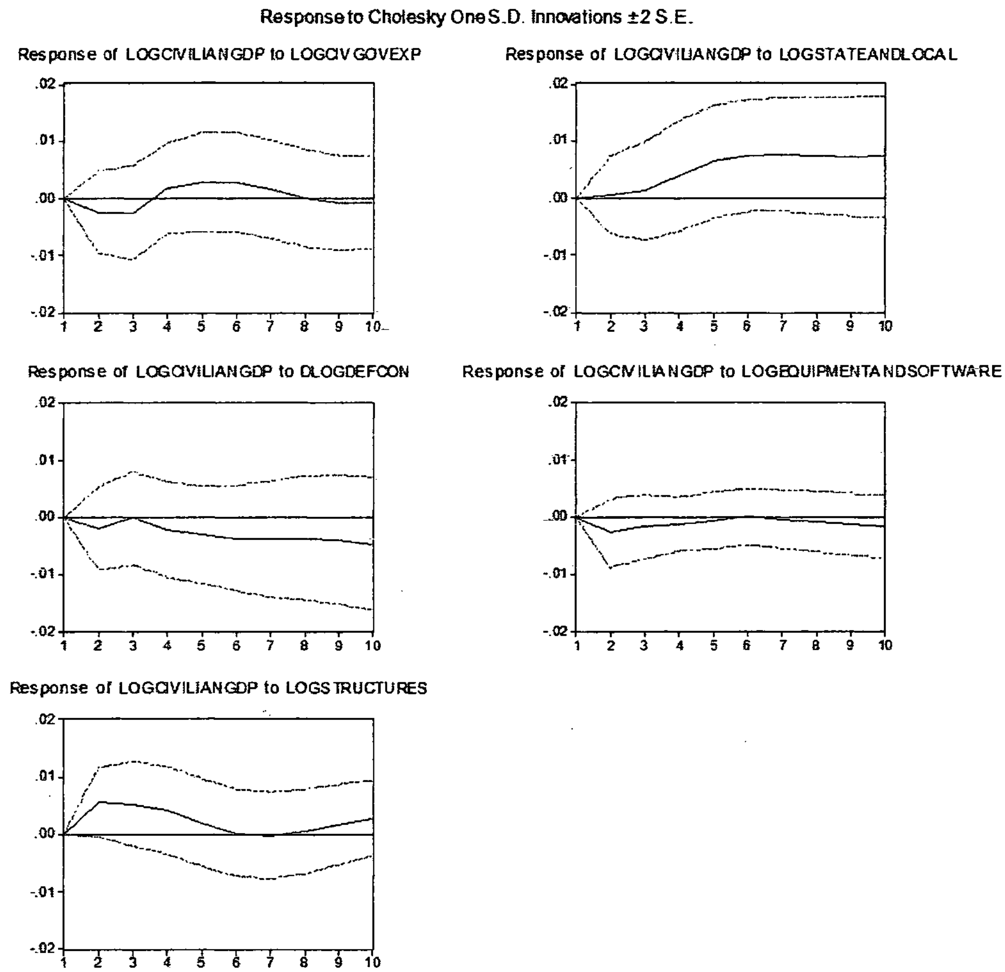

Fig. 1.2: Impulse responses for civilian GDP from table 3.

Table 1.2: Vector Error Correction Estimates

Cointegrating Equation	CointEq1	CointEq2	CointEq3
Civilian GDP	1	0	0
Federal government expenditures	0	1	0
State and local expenditures	0	0	1
Defense consumption	-179.5012	-170.1947	-185.3994
	[-3.00555]	[-3.04532]	[-2.96490]
Defense equipment and software	47.0319	43.71954	49.73706
	[5.45690]	[5.42076]	[5.51163]
Defense structures	-40.13189	-36.76757	-43.19848
	[-3.11320]	[-3.04799]	[-3.20061]
C	-108.302	-98.23363	-111.029

[1]t-statistics in brackets. All data is in log form.

Table 1.3: Co-integration Equation

	Civilian GDP	Civilian fed expendiures	State and local expenditures	Defense consumption	Defense equipment and software	Defense structures
CointEq1	-0.25202 [-1.79192]	-0.09238 [-0.31382]	0.08236 [0.97849]	0.54554 [1.89659]	0.79370 [1.58875]	-1.81514 [-2.10933]
CointEq2	0.13261 [1.43589]	-0.01169 [-0.06050]	-0.06699 [-1.21212]	-0.39813 [-2.10789]	-0.69215 [-2.10998]	0.80457 [1.42389]
CointEq3	0.12046 [2.18050]	0.09851 [0.85197]	-0.01886 [-0.57041]	-0.16537 [-1.46363]	-0.14332 [-0.73036]	1.02022 [3.01829]
Civilian GDP (t-1)	*0.06015* [0.34088]	*0.01321* [0.03578]	*0.33130* [3.13736]	*-0.10410* [-0.28847]	*-1.66629* [-2.65858]	*0.48750* [0.45156]
Civilian GDP (t-2)	-0.10569 [-0.81219]	0.33267 [1.22149]	0.10039 [1.28908]	-0.45641 [-1.71499]	-0.60258 [-1.30368]	0.99398 [1.24846]
Federal government expenditures (t-1)	-0.07995 [-0.66579]	-0.40294 [-1.60323]	-0.02146 [-0.29863]	0.37617 [1.53168]	0.30273 [0.70973]	-2.10711 [-2.86787]
Federal government expenditures (t-2)	-0.24883 [-2.18506]	-0.37654 [-1.57981]	-0.19712 [-2.89240]	-0.05634 [-0.24190]	-0.12175 [-0.30099]	-1.59960 [-2.29577]
State and local expenditures (t-1)	-0.08483 [-0.37267]	0.85077 [1.78570]	0.25053 [1.83904]	0.29808 [0.64028]	2.27137 [2.80909]	0.69462 [0.49873]
State and local expenditures (t-2)	0.03423 [0.14313]	-0.13577 [-0.27123]	-0.01211 [-0.08460]	0.80124 [1.63803]	-1.10332 [-1.29871]	1.24020 [0.84749]
Defense consumption (t-1)	-0.23743 [-1.64535]	-0.06901 [-0.22848]	-0.12202 [-1.41297]	-0.54460 [-1.84529]	-1.44699 [-2.82294]	0.83102 [0.94121]
Defense consumption (t-2)	-0.36047 [-2.67331]	-0.03687 [-0.13064]	-0.18716 [-2.31933]	-0.59552 [-2.15944]	-0.72516 [-1.51402]	0.38882 [0.47128]
Defense equipment and software (t-1)	-0.09053 [-1.54535]	-0.03066 [-0.25007]	0.02943 [0.83945]	-0.12126 [-1.01210]	-0.07732 [-0.37155]	0.27533 [0.76815]
Defense equipment and software (t-2)	0.01756 [0.33884]	0.01362 [0.12555]	-0.01210 [-0.39005]	-0.30708 [-2.89752]	-0.23684 [-1.28674]	-0.43303 [-1.36579]
Defense structures (t-1)	-0.01674 [-0.42159]	-0.11276 [-1.35652]	0.00359 [0.15108]	0.13760 [1.69404]	0.06077 [0.43080]	0.18771 [0.77247]
Defense structures (t-2)	*-0.05026* [-1.87867]	*-0.11962* [-2.13613]	*-0.00584* [-0.36499]	*0.05805* [1.06088]	*0.22972* [2.41719]	*0.37147* [2.26920]
C	0.10253 [5.46094]	0.04973 [1.26556]	0.03382 [3.01001]	-0.03444 [-0.89698]	0.14139 [2.12015]	0.04055 [0.35302]
R-squared	0.85094	0.71242	0.89551	0.51967	0.85927	0.76051
Adj. R-squared	0.71120	0.44281	0.79754	0.06936	0.72733	0.53598
F-statistic	6.08926	2.64244	9.14132	1.15402	6.51281	3.38719
Likelihood	102.71620	79.08142	119.14520	79.82081	62.15521	44.75408

[1] t-statistics in brackets. All data is in log form.

Chapter 2

The Cost of Peace: An Estimate of the Effect of Military Spending on Welfare

2.1 Introduction

Gross domestic product (*GDP*) is a theoretical construction that is designed to describe the productive capabilities of a country. It is also often used as a proxy for welfare or the strength of an economy by researchers and commentators, as well as in indices that measure welfare such as the Human Development Index. There are, however, several reasons why it is not a good indicator of a country's welfare. For one, *GDP* includes spending on security activities such as the police, courts and the military. Increasing spending on these activities does not necessarily increase the welfare of a population without increasing the relative security of that population[1]. In fact, an increase in spending may take away from welfare.

The following example illustrates the welfare implications of an arms race. Imagine a group that faces no threat of appropriation of goods; call this group *A*. All resources could potentially be spent on either socially or economically productive investment and consumption, both being important determinants of overall welfare. If this economy is suddenly faced with an outside threat of appropriation, perhaps from another group that has armed itself, call this group *B*, a portion of productive spending must be taken out and used in the production

[1] A discussion of what to include in *GDP* is addressed by (27) and (26), who argue that defense spending should be taken out of *GDP* and classified as an "instrumental" expenditure in that it is not a source of utility in itself. (33) also offers a larger discussion of what should and should not be included in *GDP*.

of protection. This may include hiring guards or building a military. Employing a police force, building tanks, fighter jets and other security provisions takes away from the welfare enhancing consumption group *A* had been enjoying. If while free of appropriation threats there was no investment taking place by the group members, then the *GDP* of the group as it is currently commonly defined would not change, though overall welfare will decrease by an amount equal to the increase in security spending. If there was investment, then some portion of this investment is lost and so both conventional *GDP* and welfare will decrease.

Assume that group *A* now arms to a level that deters *B* from ever attacking. Call this initial arming level or the number of guns held by group i, g_i, where we suppose $g_A^L = g_B^L$. There is armed peace, but welfare in both countries is lower than it could have been if $g_A^L = g_B^L = 0$. If group *B* now decides to increase spending on guns to a new level, *A* will likewise respond to deter *B* from attacking. Call this new level of spending $g_A^H = g_B^H$, where $g_i^H > g_i^L$. Security has not changed for these two groups; there is still armed peace as *B* is deterred from attacking, but welfare in each group has decreased even further.

Now, assume that before the two groups armed to levels g_A^H and g_B^H they had instead decided to negotiate or to appeal to a norm system that discourages excessive arming. They would have both enjoyed greater welfare.

This paper will explore the costs associated with all military and security spending during both peace and conflict and offer an estimate of the direct welfare cost of arming. The world is obviously more complicated than this simple model suggests as nations must face a number of threats, both real and perceived. Furthermore, it is not my intent to argue that security spending is of no value. As I argue below, security spending is determined by arming of opponents, as well as the institutions that exist. It is important then to understand the costs associated with the fact the world is dangerous and arms the way it currently does[2].

I first introduce a new term: the gross welfare product. A common definition of GDP is gross consumption plus government spending plus investment plus net exports, where security spending is part of government spending. That is, $GDP = C + G + I + NX$, where $G = S + O$, with S being resources spent on security and O resources spent on other goods and services. An economy can then be divided into a gross welfare product ($G\hat{W}P$), which is gross consumption plus government spending less security spending plus investment plus net exports, or $G\hat{W}P = C + O + I + X$, and security spending (S). This GWP is one of the many different possible corrections of GDP, and so will be denoted with a hat as it is one estimate of the welfare product of a country. For the purposes of this paper then, GDP can be broken down into two parts, with $GDP = G\hat{W}P + S$, or $G\hat{W}P = GDP - S$. This welfare product is the part of the investment and consumption of an economy that goes into final goods that add to the welfare of the people.

A common critique of such an estimate of the welfare benefits from decreased military spending is based on the argument that current levels of military spending are the equilibrium outcome of a larger game. Thus, the argument goes, any attempt to quantify the costs of military spending ignores the implications of such a game. Such a calculation, though, is not outside the normal practice of economics. For instance, when calculating any welfare loss, such as deadweight loss from taxation, there is an implicit assumption that calculating such costs is important, despite the larger political economy situation that has lead to that level of taxation. Like other welfare research, this paper looks at the deadweight loss of military spending in the hopes of understanding what the current system of spending means for economies. It does not look at whether the conditions that

[2]Recently, (36) argue the importance of understanding the costs behind the invasion of Iraq.

necessitate this spending are reasonable.

The next section looks at the existing literature on the welfare implications of security spending. In section 3, I explore the implications of a model from (35) that demonstrates how security spending can depend on institutions such as property rights and social norms, in order to argue that the inclusion of security spending in *GDP* can be misleading from a welfare perspective. Section 4 discusses the data and in section 5 I use two different definitions of security spending: S_I, which is composed of military spending only, and $S = S_I + S_D$, where S_D is domestic security. S is thus composed of both military and domestic justice spending. I discuss how not including these in *GDP* changes the growth rates and rankings of countries. I specifically focus on those countries that show the most effect: the United States and other OECD countries, as well as Pakistan and Turkey. I use S_I because of missing data, though the resulting estimates can be thought of as a lower bound for countries excluded from S.

Section 6 provides an estimate of the effects and costs of spending on security for a subsample of countries with the necessary data. I assume a Cobb-Douglas production function for each country and a minimal level of S of 2.2% for OECD countries, which is how much Ireland spent on their military, police and justice system in 2002[3]. I find that on average up to 3.5% of potential consumption is lost due to security spending, with the United States leading the group at 10% lost. Using S_I for a larger set of 134 countries, I find that an average 4.32% of potential consumption is lost due to military spending. Section 7 then concludes.

[3]This percentage is not the lowest level of security spent amoung the OECD countries as Luxemburg and Iceland have often spent less than 1.5% and 1.8% of *GDP* respectively on domestic and national security.

2.2 Transfers, Spillovers and Growth Costs

Security spending is an example of a transfer activity. (37), (19), (30), (38), (33) and (4) discuss the welfare implications of transfer activities and conclude transfers are a loss to society and reduce an economy's long-run rate of economic growth. (20) estimate the amount of resources that have been expended on transfer activities in the United States in 1985. The directly observable expenses include spending on police, locks, alarms, insurance, tort litigation, military minus R&D, lobbying and campaigning. In 1985 US$, together these expenditures totaled $456 billion, one eighth of total *GDP* in 1985, with the largest by far being military spending at $226 billion.

While the military does not generate a direct social benefit, military research and employment may have larger benefits for society. There is a long-standing debate about the spillover effects of military spending on *GDP* growth[4]. (14) find the literature is divided between the multiple-sector Feder-Ram model used in the defense literature, which often finds positive spillover effect, and mainstream growth models that find negative effects. Their analysis of the Feder-Ram model reveals a number of econometric and theoretical problems. Most importantly, technical efficiency in production is assumed by the model, and so what is argued as a measure of spillovers is logically inconsistent. Among those models that are logically consistent, spillovers from military spending are non-positive.

(18) use a growth model with panel data from 1971 to 1985 for the major

[4]The debate began with (5), who found a positive and significant relationship between military spending and economic growth in developing countries. Since then researchers have found mixed results. A small sample of those that found no effects include (11), who analyze the spillover effects of military spending for India. (6) likewise found no spillovers for cross-country regressions for low, middle and pooled samples for a sample of 58 countries from 1960 to 1977 using a two sector model where expenditures are made for consumption and military spending. (8) tests for Granger causality for the effect of military spending on *GDP* growth rates and finds that most countries do not exhibit a causal link between defense spending and economic growth, and in those that did, the relationship is negative. Through a disaggregate study of military spending, (2) finds some positive effect from R&D spending, though it is significantly smaller than fiscal spending.

regions in the world. As with the results of others in the growth literature, they find evidence consistent with the notion that military spending reduces economic growth. Using simulations, they further find that a reduction in military spending to 2% of GDP would imply an increase in the growth of GDP, with Eastern Europe the highest at 50%.

While Knight et al. and this paper ask a similar question - namely, what gains can be realized from decreasing military spending - both the time periods observed and the methods are quite different. Because Knight et al. use regression estimates, they are constrained by data availability and so must look at the issue by region. In this paper, I look at the effect on each individual country by assuming a production function. My approach assumes a functional form to production but does not require the estimation of a growth model. As such, my estimates of the effects of reduced security spending reveal some of the differences between countries within regions. For instance, Knight et al. show a small effect from decreased military spending in the West, while I find that the United States would be the largest to gain from reduced spending. These differences are also due in part to Knight et al. imposing strong assumptions on future patterns of growth, such as convergence among countries. This paper makes no assumptions about growth rates, future, or past.

2.3 Model of Security Spending

Why do some countries spend more than others on their militaries, police and justice systems? In this section I explore a model from (35) that shows how the final consumption of a populace can be influenced by the arming of opponents, such as the arms race described above, but also security of property and norms of division which are assumed to be determined exogenously from the model by society.

Assume there are two groups, A and B, who have an exogenously determined total income of Y. Let A and B each have secure possession of some share of Y, call it σ_a and σ_b respectively, with $\sigma = \sigma_a + \sigma_b \in [0,1]$. This σ_i can be thought of as a property right. The income is secure for each group i and cannot be taken away by the other group. For example, modern nations may have disputes over borders (such as the boundary disputes between Ethiopia and Eritrea) or over regions (such as conflict between India and Pakistan over Kashmir), but, with the exception of Iraq's invasion of Kuwait, most countries do not look to conquer full territories. The two parties then compete for $(1-\sigma)Y$ through arming. If they fight, some amount, $\phi \in (0,1)$, is lost.

The two countries move in the following order:

1. A and B choose level of arming g_a and g_b respectively, where g can be thought of as the number of guns built, or the amount of either S or S_I.

2. Each side decides to either fight or divide the contested income according to some decision rule. Specifically, A receives $v^{\beta}(g_a, g_b)$ and B receives $1 - v^{\beta}(g_a, g_b)$.

Skaperdas considers decision rules that always yield settlement as part of the subgame perfect equilibrium, such as those of the following form:

$$v^{\beta}(g_a, g_b) = \beta \frac{g_a}{g_a + g_b} + \frac{(1-\beta)}{2} \tag{2.1}$$

where:

- $\beta = 0$: Insecure income is divided in half.

- $\beta = \phi$: Divided according to symmetric bargaining solution.

- $\beta = 1$: Divided according to probability of winning.

In this case, β can be a norm of division between the groups that has been determined exogenously. For example, how England treated the American versus African versus Indian colonies is an example of a nation having different division rules β. When faced with rebellion in America, the British did not engage in the same brutal tactics they employed in Africa and India. There are a number of reasons for the difference in tactics, some of them strategic, though the norms of engagement and expectations of how eventual division would be handled was clearly an important determinant.

Note that the probability of success in the war is determined by $\frac{g_i}{g_a+g_b}$, a contest success function where the relative level of armament determines the expected probability of winning.

If they fight, their expected income is:

$$Y_i^f(g_a, g_b) = \sigma_i Y + \frac{g_i}{g_a + g_b}(1-\phi)(1-\sigma)Y - g_i \tag{2.2}$$

If they settle, their expected income is:

$$Y_a^\beta(g_a, g_b) = \sigma_a Y + v^\beta(g_a, g_b)(1-\sigma)Y - g_a \tag{2.3}$$

$$Y_b^\beta(g_a, g_b) = \sigma_b Y + (1 - v^\beta(g_a, g_b))(1-\sigma)Y - g_b \tag{2.4}$$

Comparing equation (2) with equation (3), country A will then settle iff

$$v^\beta(g_a, g_b) \geq \frac{g_a}{g_a + g_b}(1-\phi) \tag{2.5}$$

The Nash equilibrium choice of guns is then

$$g_a^{\beta} = g_b^{\beta} = g^{\beta} = \beta\frac{(1-\sigma)Y}{4} \tag{2.6}$$

while equilibrium consumption for each country is thus

$$Y_i^{\beta}(g^{\beta}, g^{\beta}) = \sigma_i Y + \frac{(2-\beta)}{4}(1-\sigma)Y \tag{2.7}$$

The total consumption per group thus depends on the arming of each group, which itself depends on the rules of division, β, as well as the property rights, σ, that exist within the system. These parameters could be the result of past spending on arming, or the results of social boundaries or local institutions. For instance, as described previously, σ could be determined by international norms, which in the last few years have made the unprovoked invasion of another country outside of normal practice. The only recent case of an unprovoked invasion, the invasion of Kuwait by Iraq, resulted in a large international force that repelled the invading army. The final consumption of a populace is therefore influenced by the arming by opponents as well as security of property and norms of division which can be exogenously determined by society.

From this model and the description of an arms race in the introduction, we can see that there are many elements that can determine the amount of spending by a nation or group on international security S_I and domestic security S_D. For military spending, different international norms, levels of security of territory and the relative spending of other nations yields different levels of spending on arms but do not necessarily mean more or less security from appropriation by foreign powers. Domestic security is an attempt to stop appropriation by domestic criminals and is likewise affected by different local and cultural norms; levels of security of territory, such as property rights within a nation; and the relative spending of criminals on arms. Greater spending on domestic security then does not necessarily mean more or less security from appropriation by domestic thieves.

Thus, security spending can be vastly different between nations or over time within any given nation as institutions evolve. While security spending can have positive effects on an economy, including such spending in welfare comparisons can be misleading. Norms and arming by opponents can change over time, making comparisons across time difficult. For instance, if two countries engage in an arms race, the welfare they enjoyed before the arms race will decrease without more security being attained; but by including security spending in *GDP*, it would appear that welfare is the same.

As there are elements beyond arming that can affect security spending, the decisions of leaders and the institutions that exist within a given context can have a great impact on this spending. It is thus important to understand the costs associated with a dangerous world. The remainder of this paper explores the implications of including security spending in *GDP* and the welfare implications of this spending.

2.4 Data

To estimate the welfare implications of security spending, I use data on *GDP*, total labor force, and gross capital formation for each country in constant 2000 US$ from the World Development Indicators ((39)). S security spending is collected from (28) for each of the OECD countries and includes budgeted amounts of spending on the military, including intelligence, police forces and judicial system, which is the total spending on courts, lawyers, judges and prisons. Greece is omitted because of missing data. As data on courts, lawyers, judges and prisons are not available for countries outside of the OECD, S_I is for military spending only and is collected from (34) for each country[5]. Using S_I then creates a lower bound for countries excluded from S.

Table 1 lists all of the countries included in the full sample. Table 2 shows the summary statistics across all countries in the full sample for S_I military expenditures from 1991 to 2005. There is a very large difference between countries for all variables. The largest spending countries as a percentage of income are poorer or Middle Eastern countries. For instance, the countries with the largest military expenditure as a percent of GDP in 2004 are Oman (12%), Israel (9%), Saudi Arabia (8%), Jordan (8%) and Kuwait (7%); the United States is at 15 with 4%. The five largest spenders per capita in constant 2000 US$ are Israel ($1554), United States ($1450), Kuwait ($1445), Singapore ($1167) and Oman ($1098). For S, in 2004, the highest per capita spenders were the United States ($2,442), United Kingdom ($1,462) and Norway($1,259), while the lowest were the Czech Republic ($244), Slovenia ($352) and Portugal ($419).

2.5 New Estimates of Growth Rates

Countries are often ranked and compared according to GDP growth rates. In this section, I look at per capita growth rates for $G\hat{W}P$ and compare these results to GDP growth rates. Let $\Delta G\hat{W}P_t = G\hat{W}P_t - G\hat{W}P_{t-1}$, and lower case letters denote per capita growth rates. For example, $g\hat{w}p = \frac{\Delta G\hat{W}P_t}{G\hat{W}P_t}$. Table 3 presents the rankings for gdp and $g\hat{w}p$ for 2004 in the given economy.

Tables 4 and 5 show $g\hat{w}p - gdp$ for the OECD countries and the full sample respectively. When this number is negative, security spending S or S_I is either

[5]The data on military spending from SIPRI for the United States does not include funding for the Department of Energy nuclear weapons program and numerous other agencies and foreign financing. (40) has collected data on the full United States funding of wars since 1998. After careful scrutiny of the data, the inclusion of this additional data does not substantially change the results, and so I use the SIPRI data exclusively to ensure comparability across countries.

decreasing, or *GDP* growth rates are being pushed upward by increases in security deficit spending[6]. Using the broader measure of security spending (S), the United States had a difference of -0.53 between $g\hat{w}p$ and gdp in 2002, which was all of the growth of the United States economy in that year. Increased security spending thus accounted for all of *GDP* growth in 2002.

Among the OECD countries, the economies with the largest differences between $g\hat{w}p$ and gdp in 2004 are the Czech Republic (0.65%), Italy (0.42%) and Sweden (0.22%), while the countries with the smallest difference were Finland (-0.21%), the United States (-0.11%), Spain (-0.10%) and Denmark (-0.10%).

Table 6 shows more detailed results for the United States, Pakistan and Turkey over the period 1997 to 2005 using S_I. The United States offers an interesting historical case for welfare growth versus standard *GDP* accounting. Before 2001, the difference between $G\hat{W}P$ and *GDP* growth for the United States was positive, meaning United States welfare per capita was increasing at a faster rate than thought. By contrast, in 2004, under S_I, the United States had a difference of -0.19 between $G\hat{W}P$ and *GDP* growth. As the United States' was increasing military spending at the time, this means that United States' welfare growth per capita was less than *GDP* growth in 2004 by 0.19 percentage points. This is a considerable number as *GDP* growth per capita for the United States in 2004 was 3.22%.

[6] This is the case because

$$\begin{aligned}
\Delta G\hat{W}P_t &= \Delta GDP_t - \Delta S_t \\
\Rightarrow g\hat{w}p_t &= \frac{\Delta GDP_t - \Delta S_t}{G\hat{W}P_t} \\
\Rightarrow g\hat{w}p_t &= gdp_t \frac{GDP_t}{G\hat{W}P_t} - s_t \frac{S_t}{G\hat{W}P_t} \\
\Rightarrow g\hat{w}p_t - gdp_t &= gdp_t \left(\frac{GDP_t}{G\hat{W}P_t} - 1 \right) - s_t \frac{S_t}{G\hat{W}P_t} \\
\Rightarrow g\hat{w}p_t - gdp_t &= \frac{S_t}{G\hat{W}P_t}(gdp_t - s_t)
\end{aligned}$$

The sign of $g\hat{w}p_t$ - gdp_t will thus be determined by the difference between gdp_t and growth in security s_t.

During the last part of the 1990s, the growth rate of per capita welfare was increasing faster than indicated by GDP per capita growth as security spending was decreasing for much of the period. From 1999 onward, spending on security increased for the first time in many years. Until 2001, however, the difference between $\hat{gwp}$ and gdp was still positive as per capita income was growing faster than S. In 2001 this switched. Security spending continued to increase, led in part by increases in military spending, but $\hat{gwp} - gdp$ became negative. In 2001, per capita income actually fell, but welfare fell by more than reflected in GDP. The growth rate of $G\hat{W}P$ since 2001 has been increasing, but still much lower than reflected in GDP.

In 2004, using S_I, the economies with the largest positive differences between $G\hat{W}P$ and GDP are all developing countries, with most coming from the Middle East. For example, Pakistan displays a similar trend to the United States with an overstatement of welfare growth from 2001 to 2003. During these periods military spending increased more than GDP. Since 2004, though, the effect has reversed. Turkey has had the opposite experience from the United States Before 2000, $\hat{gwp} - gdp$ was negative, reaching almost 1%, during periods of high increases in military spending. Since 2000, though, this has changed as Turkey has been decreasing military spending.

2.6 Production Loss

If, as most research in the growth literature finds, security spending has no spillover effects, *a priori* we know there is a difference between the actual $G\hat{W}P$ of a country and the potential $G\hat{W}P$ that could have been realized if some or all of security spending had in fact been used for investment. This section will estimate the size of this difference in potential and actual $G\hat{W}P$ for all countries with full data.

To estimate the production loss associated with spending on security activities, assume each country produces goods according to a Cobb-Douglas production function of the following form:

$$Y_{it} = A_{it} K_{it}^{\alpha} L_{it}^{\beta} \tag{2.8}$$

where

$$K_{it} = \sum_{\tau=0}^{t} (1-\rho)^{t-\tau} K_{i\tau} \tag{2.9}$$

For country i at time t, Y is GDP, K is capital, L is labor and A is the Solow residual, or total factor productivity. α and β are given parameters that determine the relative amount of inputs K and L. ρ is the depreciation rate of capital, so K_t is the stock of capital accumulated up to time t. The calculation of capital as a sum of previous discounted capital accumulation is taken from (25), which includes a good description of this and other ways of calculating capital stock.

To calculate the welfare lost from security spending, we must find the difference between actual $G\hat{W}P$ and the potential $G\hat{W}P$ that could have been realized if some security resources had in part been used for welfare enhancing consumption and investment. I first estimate total factor productivity A for each of the countries in the sample for which data on capital accumulation are available. Potential $G\hat{W}P$, or $\overline{GWP}$, is then determined by including reinvested security spending, $\overline{S_i}$, in a productive use. In this case, some amount is invested in capital accumulation and the rest is consumed. I assume constant returns to scale with $\alpha = 0.33$ and $\beta = 0.67$, which fall within the range of $\beta \in [0.65, 0.80]$ that was found by (16) to be an accurate representation of the labor share for most countries. Depreciation is assumed to be 5% as in (25).

I determine potential $\hat{GWP}$ for a given country as follows:

First, assume that a certain amount of security spending, $\gamma \in [0,1]$, is used instead for investment purposes and the remaining, $1-\gamma$, is used in consumption. Potential accumulated capital is then $\overline{K_t} = K_t + \sum_{\tau=0}^{t}(0.95)^{t-\tau}\gamma\overline{S_\tau}$, with $\tau < t$. Thus,

$$\overline{GWP_{i,t}} = A_{i,t}(\overline{K_{i,t}})^{0.33}(L_{i,t})^{0.67} + (1-\gamma)\overline{S_{i,t}} \tag{2.10}$$

Total welfare loss as a percent of current welfare is then $\frac{\overline{GWP_t}-\hat{GWP_t}}{\hat{GWP_t}}$. As capital is accumulated over time, the full effect of using security spending for investment needs to also be accumulated over time[7]. The results are for 2004 and assume that excess security spending has been invested in each economy since 1991.

For the OECD countries, using the broader measure of security spending, the average amount spent on security in 2004 was 3.8% of *GDP*. I assume here a minimum spending level for security of 2.2%, which is the average spending level of Ireland from 2002 to 2004. This number is used as a theoretical lower bound on what nations may need to spend on security. Because of missing data, the number of countries has been reduced to 59 when using S_I. The average amount spent on the military in 2005 was 1.83% of *GDP*, which is lower than the total world average of 2.92%. There are thus a number of countries that have higher than average levels of spending on the military (those countries that would be affected the most from not spending on the military) that are missing from this sample, and so this average is a minimum for the world average.

Table 7 presents this percentage difference between GDP and $\overline{GWP}$ for countries using both measures of security spending under the assumption that γ, the amount of reinvested security spending instead spent on investment, is 0.10, or 10% of security spending (the rest, 90%, is then used for consumption), and for

[7] L has not changed for potential $\hat{GWP}$ as I assume that the population of workers in the security sector has moved into the non security sector at a similar marginal productivity.

$\gamma = 1.00$[8].

The average loss using the broader measure of security spending over these years was 3.28% for $\gamma = 0.10$ and 3.55% for $\gamma = 1.00$. This number is the welfare increase, on average, that an individual could have realized each year had security spending been used for investment alone or both consumption and investment. These numbers are significant for most countries, but are especially big for the United States and United Kingdom. Under S, the reinvested amount of security spending for the United States in 2004 is assumed to be 6.7% - 2.2% = 4.5%, while potential $G\hat{W}P$ gains are 9.49%, over twice the amount of reinvested spending. For the United Kingdom, reinvested spending is at 5.5% - 2.2% = 3.3%, again less than a half of the potential benefits of 6.94%. This effect is due to the high returns to investment in the OECD countries. There are thus large potential gains from decreasing security spending in all of the OECD countries.

Using the narrower measure of security spending S_I, the sample world average over these years was 3.81% for $\gamma = 0.10$ and 4.23% for $\gamma = 1.00$. The countries in this sample that have the biggest potential increase in welfare are Pakistan (10%), the United States (9.34%), Morocco (9%), Chile (8.44%), Columbia (8.39%), Zimbabwe (8.13%) and Iran (7.42%). All of these numbers are large and suggest that for much of the world the cost to welfare of military spending are quite high.

2.7 Conclusion

In this paper, I have argued that including security activities in GDP is misleading from a welfare perspective by using a model of conflict that demonstrates how the levels of both arming and security for a nation or people depends on multiple

[8]Note that $\gamma = 1.00$ is not necessarily welfare maximal. To see this, take the partial derivating of $\overline{GWP}$ with respect to γ. The maximum value of potential GWP can be at γ less than 1 as it depends on a number of parameter values. In some cases then, the potential loss of welfare under $\gamma = 0.10$ can be greater than the potential loss of welfare under $\gamma = 1.00$

factors, including property rights and social norms. Once security spending is removed from the conventional measure of *GDP*, I find that welfare growth rates change dramatically for a number of countries. The most dramatic change is for the United States, where all *GDP* growth in 2002 is due to increases in security spending. The use of *GDP* as a proxy for welfare in research and indices can thus be very misleading.

I also find an average of over 4% welfare enhancing production loss per country is due to security spending, with the United States again being the highest at 10%. While it is not likely that the world will ever reach a state where all attempts at appropriation cease, it is important to understand the size of the costs associated with the fact that the world is dangerous and arms the way it currently does.

Table 2.1: Countries in full sample. Those with a * are in the OECD sample as well.

Albania	Djibouti	Kyrgyz Republic	Romania
Algeria	Dominican Republic	Lao PDR	Russian Federation
Angola	Ecuador	Latvia	Rwanda
Argentina	Egypt	Lebanon	Saudi Arabia
Armenia	El Salvador	Lesotho	Senegal
Australia	Equatorial Guinea	Liberia	Serbia and Montenegro
Austria*	Eritrea	Libya	Seychelles
Azerbaijan	Estonia	Lithuania	Sierra Leone
Bahamas	Ethiopia	Luxembourg*	Singapore
Bahrain	Fiji	Macedonia	Slovak Republic
Bangladesh	Finland*	Madagascar	Slovenia*
Belarus	France*	Malawi	South Africa
Belgium*	Gabon	Malaysia	Spain*
Belize	Gambia	Mali	Sri Lanka
Benin	Georgia	Malta	Sudan
Bolivia	Germany*	Mauritania	Swaziland
Bosnia and Herzegovina	Ghana	Mauritius	Sweden*
Botswana	Greece	Mexico	Switzerland
Brazil	Guatemala	Moldova	Syrian Arab Republic
Brunei	Guinea	Mongolia	Tajikistan
Bulgaria	Guinea-Bissau	Morocco	Tanzania
Burkina Faso	Guyana	Mozambique	Thailand
Burundi	Haiti	Namibia	Togo
Cambodia	Honduras	Nepal	Trinidad and Tobago
Cameroon	Hungary	Netherlands*	Tunisia
Canada	Iceland*	New Zealand	Turkey
Cape Verde	India	Nicaragua	Turkmenistan
Central African Republic	Indonesia	Niger	Uganda
Chad	Iran	Nigeria	Ukraine
Chile	Ireland*	Norway*	United Arab Emirates
China	Israel	Oman	United Kingdom*
Colombia	Italy*	Pakistan	United States*
Congo, Dem. Rep.	Jamaica	Panama	Uruguay
Congo, Rep.	Japan*	Papua New Guinea	Uzbekistan
Cote d'Ivoire	Jordan	Paraguay	Venezuela
Croatia	Kazakhstan	Peru	Vietnam
Cyprus	Kenya	Philippines	Yemen
Czech Republic*	Korea, Rep.*	Poland	Zambia
Denmark*	Kuwait	Portugal*	Zimbabwe

Table 2.2: Summary of *GDP* and military expenditures, averaged across the sample of 156 countries from 1991 to 2005.

	Mean	S.D	Min	Max
Percent *GDP* per capita growth rate (2000 US$)	1.633	2.503	-5.259	16.893
Military expenditures (% of *GDP*)	2.924	3.333	0.00	24.581
Military expenditures per capita	150.734	286.283	0.00	1632.621

Table 2.3: Rankings for *GDP* and $G\hat{W}P$ per capita growth rates for 2004 in percent.

Top10	*GDP* per capita growth rate		$G\hat{W}P$ per capita growth rate	
	Chad	25.19	Chad	25.72
	Venezuela, RB	15.81	Venezuela, RB	15.85
	Ukraine	12.98	Ukraine	13.27
	Belarus	12.01	Belarus	11.95
	Uruguay	11.04	Uruguay	11.43
	Armenia	10.91	Ethiopia	11.09
	Ethiopia	10.14	Armenia	11.05
	China	9.44	China	9.50
	Tajikistan	9.39	Tajikistan	9.46
	Azerbaijan	9.24	Azerbaijan	9.42
Bottom 10	*GDP* per capita growth rate		$G\hat{W}P$ per capita growth rate	
	Italy	0.07	Morocco	0.39
	Central African Republic	0.05	Yemen, Rep.	0.26
	El Salvador	0.04	Central African Republic	0.15
	Brunei	-0.54	Italy	0.10
	Yemen, Rep.	-0.66	El Salvador	0.07
	Mali	-0.83	Mali	-0.89
	Malta	-2.14	Malta	-2.20
	Seychelles	-2.97	Niger	-3.47
	Niger	-3.31	Seychelles	-3.49
	Zimbabwe	-4.34	Zimbabwe	-5.50

[1] $G\hat{W}P$ is *GDP* without military spending. Negative values show an over-estimation of welfare growth when using *GDP* alone.

Table 2.4: $G\hat{W}P$ growth rate - *GDP* growth rate per capita for OECD countries.

Country	2000	2001	2002	2003	2004
Austria	0.11	0.10	0.00	-0.10	0.10
Belgium	0.00	-0.10	-0.10	0.00	.
Czech Republic	.	.	.	-0.32	0.65
Denmark	0.21	-0.10	0.00	0.00	-0.10
Finland	0.22	0.10	0.00	-0.21	-0.21
France	0.22	-0.11	-0.10	0.10	0.00
Germany	0.00	0.00	0.00	0.10	0.10
Iceland	0.00	0.00	0.00	-0.10	0.00
Ireland	0.11	0.00	0.21	0.11	-0.10
Italy	0.11	0.00	-0.10	-0.31	0.42
Japan	0.00	0.00	0.00	0.00	0.00
Korea	0.11	0.11	0.00	0.00	0.00
Luxembourg	0.00	-0.10	0.00	-0.10	0.00
Netherlands	.	.	-0.10	0.00	0.00
Norway	0.64	0.00	-0.42	0.21	0.21
Portugal	-0.11	0.11	-0.10	0.00	0.00
Slovenia	.	-0.21	-0.11	0.00	0.00
Spain	.	-0.11	0.00	0.10	-0.10
Sweden	0.22	0.11	0.00	0.11	0.22
United Kingdom	-0.43	0.00	0.00	-0.22	0.11
United States	0.11	-0.21	-0.53	-0.43	-0.11

[1] $G\hat{W}P$ is *GDP* without military, police and justice spending. $G\hat{W}P$ - *GDP* is the difference between estimated welfare growth and published *GDP* growth rates per capita. Negative values show an over-estimation of welfare growth when using *GDP* alone.

Table 2.5: Rankings for $G\hat{W}P$ growth rate - GDP growth rate per capita for 2004 in percent.

Top 10	$G\hat{W}P$ - GDP per capita growth rate	
	Jordan	1.05
	Ethiopia	0.95
	Yemen, Rep.	0.92
	Burundi	0.90
	Turkey	0.74
	Syrian Arab Republic	0.58
	Sierra Leone	0.56
	United Arab Emirates	0.56
	Chad	0.53
	Bahrain	0.52
Bottom 10	$G\hat{W}P$ - GDP per capita growth rate	
	United States	-0.19
	Iran	-0.19
	India	-0.20
	Morocco	-0.33
	Georgia	-0.33
	Chile	-0.44
	Seychelles	-0.52
	Congo, Dem. Rep.	-0.96
	Zimbabwe	-1.16
	Angola	-2.22

[1]$G\hat{W}P$ is GDP without military spending. $G\hat{W}P$ - GDP is the difference between estimated welfare growth and published GDP growth rates per capita. Negative values show an over-estimation of welfare growth when using GDP alone.

Table 2.6: Growth rates for various countries from 1994 to 2005.

	1997	1998	1999	2000	2001	2002	2003	2004	2005
United States									
GDP per capita growth rate	3.3	3.01	3.3	2.52	-0.33	0.54	1.86	3.22	2.24
Military expenditure per capita growth	-1.06	-2.97	-0.17	3.9	0.13	10.91	13.12	7.99	4.95
Military expenditure (% of *GDP*)	3.35	3.15	3.05	3.09	3.1	3.42	3.8	3.98	4.08
$G\hat{W}P$ per capita growth rate	3.46	3.22	3.41	2.48	-0.35	0.21	1.46	3.03	2.13
Growth $G\hat{W}P$ - Growth *GDP*	0.16	0.21	0.11	-0.04	-0.01	-0.33	-0.4	-0.19	-0.11
Pakistan									
GDP per capita growth rate	-1.38	0.11	1.19	1.78	-0.57	0.76	2.45	3.85	5.22
Military expenditure (% of *GDP*)	5.43	5.22	5	4.05	4.08	4.28	4.31	3.96	3.36
Military expenditure per capita growth	-8.14	-3.69	-3.09	-17.48	0.02	5.76	3.23	-4.74	-10.68
$G\hat{W}P$ per capita growth rate	-0.96	0.33	1.43	2.79	-0.59	0.55	2.42	4.24	5.87
Growth $G\hat{W}P$ - Growth *GDP*	0.42	0.22	0.24	1.01	-0.02	-0.21	-0.04	0.39	0.66
Turkey									
GDP per capita growth rate	5.61	1.28	-6.34	5.56	-8.99	6.24	4.17	8.26	6.02
Military expenditure (% of *GDP*)	4.1	4.38	5.38	5.02	4.96	4.36	3.77	3.11	3.23
Military expenditure per capita growth	4.69	8.2	15.02	-1.65	-10.05	-6.51	-10.03	-10.65	9.99
$G\hat{W}P$ per capita growth rate	5.65	0.99	-7.32	5.98	-8.94	6.91	4.82	9	5.89
Growth $G\hat{W}P$ - Growth *GDP*	0.04	-0.3	-0.98	0.41	0.06	0.67	0.65	0.74	-0.13

[1] $G\hat{W}P$ is *GDP* without military spending. $G\hat{W}P$ - *GDP* is the difference between estimated welfare growth and published *GDP* growth rates per capita. Negative values show an over-estimation of welfare growth when using *GDP* alone.

Table 2.7: Percent differential of $G\hat{W}P$ by country in 2005 for subsample of countries.

	$\gamma = 0.10$	$\gamma = 1.00$		$\gamma = 0.10$	$\gamma = 1.00$
Algeria	5.72	5.20	Kenya	3.05	3.81
Argentina	2.04	2.78	Korea, Rep.	5.27	5.00
Australia	3.63	3.71	Lesotho	4.77	4.25
Bangladesh	2.35	2.79	Madagascar	2.97	3.43
Belgium*	2.23	2.25	Malawi	1.50	1.55
Bolivia	3.99	5.08	Malaysia	3.91	4.23
Brazil	3.24	3.60	Mali	3.81	3.95
Burkina Faso	3.03	3.32	Mexico	0.80	0.96
Cameroon	2.70	2.88	Morocco	8.97	9.00
Canada	2.36	2.81	Netherlands	3.26	3.53
Chile	7.94	8.44	New Zealand	2.07	2.39
China	4.00	3.55	Norway*	2.07	2.54
Colombia	7.83	8.39	Pakistan	7.29	10.00
Denmark*	1.83	1.95	Paraguay	1.57	2.01
Dominican Republic	1.25	1.59	Peru	2.58	3.02
Ecuador	4.90	4.39	Philippines	1.71	2.24
Egypt, Arab Rep.	5.91	6.83	Portugal	4.39	4.41
El Salvador	1.33	2.01	Rwanda	4.65	6.37
Finland*	2.85	2.92	Senegal	3.14	3.83
France	5.20	5.97	South Africa	2.99	3.88
Gambia, The	0.75	1.28	Sri Lanka	5.55	6.20
Germany*	1.65	1.94	Sudan	4.76	5.81
Ghana	1.49	1.35	Swaziland	3.51	3.95
Guatemala	0.90	1.46	Sweden	3.27	4.14
Guinea-Bissau	6.48	6.99	Thailand	2.34	2.61
Hungary	2.73	3.06	Tunisia	3.04	3.16
India	5.91	5.79	United Kingdom*	6.94	7.83
Indonesia	1.92	2.13	United States*	9.49	9.83
Iran, Islamic Rep.	9.16	7.42	Uruguay	2.96	4.53
Italy*	2.46	2.67	Venezuela, RB	2.38	2.93
Japan	1.96	1.86	Zimbabwe	7.19	8.13
			AVERAGE	3.81	4.23

[1]Countries denoted with a * are in the OECD sample and γ is the ratio of military, police and justice spending over 2.2% of *GDP* invested in capital. For countries without a *, γ is the ratio of military spending invested in capital. AVERAGE is the average of the values across all countries in the subsample.

CHAPTER 3

RAINFALL AND ECONOMIC GROWTH

3.1 INTRODUCTION

In 1875, William Stanley Jevons famously argued that variations in sunspots affect the power of the sun's rays, thus influencing the return of agriculture harvests, which in turn affects business confidence, leading to business crises. While his attempt to connect the incidence of a natural phenomenon to the larger business cycle eventually failed, Jevons began a search for the effect of natural cycles on agriculture - and the larger economic system - that has recently regained momentum. Research on the effect of climate change (e.g. (12), (7) and (31)) and the role of economic shocks on the incidence of conflict (e.g. (23), (10), (3) and (13)) has brought increased interest in understanding how changes in rainfall (hereafter referred to as rainfall shocks) affects an economy. Recent work - with the exception of (12), who use a dummy variable framework to control for high and low levels of rainfall - has focused exclusively on Sub-Sahara Africa and has failed to find a strong connection between rainfall growth and GDP growth for a larger set of countries.

Poor rainfall, like the sunspots envisioned by Jevons, can affect an economy through decreased productivity in the agriculture sector, potentially spilling over to other sectors. The common argument for only studying countries in Sub-Sahara Africa is that agriculture contributes substantially to their economies. Most economies in Latin America and Asia though are likewise tied to their agriculture sectors, along with many industrialized economies where agriculture is a small but still significant portion of GDP. On average, Sub-Saharan African countries have the highest percent of population in rural areas (70%) and highest land devoted to agriculture (49%), along with the lowest percent of irrigated land of any region (4.5%). While no one region has such similarly low numbers, Asia has a comparable rural population (69%), Latin America has a similarly low amount of irrigated land (14%) and Eastern Europe has the same percent of land in agriculture (49%) ((39)). Unless we believe rainfall is important only if *all* of these conditions are met, there is no *a priori* reason that Sub-Saharan Africa is a special case for the effects of rainfall. As the effects of climate change will mean greater variance in rainfall for all countries of the world, it is critical to understand the implications of rainfall for a broader set of countries.

This paper studies the lack of significance beyond Sub-Saharan Africa by exploring additional explanations for the effect of rainfall shocks on an economy. Most importantly, previous studies have failed to account for the non-linear effect of rainfall on economic growth[1]. An increase in rainfall is a benefit to agriculture, up to a point. If rainfall is too great, flooding for instance may occur, thus destroying crops.

Figure 1 shows a simple relationship between rainfall growth and economic growth for Bolivia, Trinidad and Tobago and Guinea. When rainfall and economic growth share such an inverse parabola relationship, an increase in rainfall will lead to economic growth at first, but too much rainfall will eventually hurt growth. This effect is tested for by including a quadratic term for rainfall. A significant effect for the full balanced sample of countries from 1982 to 1999 is then found. A region dummy interaction specification suggests that rainfall does matter for economic growth for countries outside of Sub-Sahara Africa, and that this relationship is an inverse parabola where lag effects matter.

[1] I am only aware of three studies that include non-linear effects for rainfall, all at the micro level: (29) explores the second order effects of rainfall shocks for savings in Thailand, (9) use squared normalized rainfall in India as an exogenous disaster shock and (32) look at the effect of non-linear temperature for crop production in the United States.

Another explanation for the lack of studies controlling for the non-linear effect of rainfall may be due to an incorrect specification of lags. For instance, (23), who only use one lag for rainfall growth, note that they attempted to use a squared term and did not find it significant. Including more than one lag allows for a greater study of the long-run impact of rainfall; for most regions outside of Africa, the economic effect of rainfall are delayed. This suggests that Africa is a special case, though far from the only region affected by rainfall.

An exploration of the channels of the effects of rainfall reveals that a reason for the importance of longer lag specification for countries outside of Sub-Saharan Africa is on the effect of rainfall on industry. For industrial value added the effect is delayed, meaning that rainfall shocks may affect even nations with little agriculture through consumption decreases originating in the agriculture sector. Thus, an possible reason why rainfall matters outside of Africa is this effect on industry.

Finally, this paper explores how good property rights institutions, which many nations in Sub-Sahara Africa are lacking, could alleviate the negative effects of shocks by preparing farmers. For instance, one of the direct effects of climate change is an increase in variance of rainfall, thus increasing the incidence of both high positive and high negative rainfall shocks. Good institutions could dampen the negative effects of these shocks by encouraging agricultural producers to invest in better infrastructure, such as irrigation, and mitigating against risk through insurance and optimal crop choice. The importance of institutions for economic performance has been discussed by a number of researchers (e.g. (17), (22), (1) and (21)). (15), for instance, finds that ethnic diversity interacted with institutions has a significant effect on the incidence of civil conflict. Evidence is found here that such broad-based institutions can help in alleviating the negative effects of rainfall shocks.

The remainder of this paper is organized as follows: section 2 presents the main empirical specification, which includes a discussion of the theoretical and empirical model used to study the impact of environmental shocks on economic growth, the data, and empirical findings for the world and by region. Section 3 explores the channels of this effect through agriculture and industrial value added also by region. Section 4 then explores the role of property rights institutions in decreasing the negative effects of rainfall shocks. Section 5 concludes.

3.2 Main Empirical Specification

3.2.1 Model

Following (12), consider an economy with Y total production and L population where production is determined as follows:

$$Y_{it} = exp\left(\beta X_{it} + \sum_{j=0}^{N}(\gamma_{1j}R_{i,t-j} + \gamma_{2j}R^2_{i,t-j})\right) \cdot L^A_{it} \tag{3.1}$$

where i refers to the individual country, t is time, A is labor productivity, X is other influencing variables and R is rainfall.

In this specification, rainfall enters through both contemporaneous and N lagged effects as rainfall shocks are likely to have long-run persistence effects in an economy as the shocks affect both current and future production, as well as consumption levels throughout the rest of the economy. Rainfall also enters in both first and second orders.

Taking logs and differencing with respect to time, the following estimatable equation is obtained, with lower case representing growth rates:

$$y_{it} = \alpha + \beta x_{it} + \sum_{j=0}^{N}(\gamma_{1j}r_{i,t-j} + \gamma_{2j}r^2_{i,t-j}) + \theta LogL_{it} + \epsilon_{it} \tag{3.2}$$

Where ϵ is the error term. The γ coefficients then capture the effects of rainfall growth on y.

In addition to the main specification, the interaction effects for region dummies and institutions is explored. Assuming I is the interaction variable leads to the following model:

$$y_{it} = \alpha + \beta x_{it} + \sum_{j=0}^{N}(\gamma_{1j} r_{i,t-j} + \gamma_{2j} r_{i,t-j}^2) + \sum_{j=0}^{N}[\delta_{1j}(r_{i,t-j} \cdot I_i) + \delta_{2j}(r_{i,t-j}^2 \cdot I_i)] + \omega I_i + \epsilon_{it} \quad (3.3)$$

In this specification, δ captures the interaction effect and is the variable of interest. Such a specification allows for more than just controlling for differences across nations by capturing the specific effect of these differences.

3.2.2 Data

The descriptive statistics for all data is presented in table 1 and table 2 lists the countries in the sample.

Rainfall comes from an expanded balanced data set from (23) from 1982 to 1999. Three different monthly measures of rainfall were collected and aggregated by year by Miguel et al. from the Global Precipitation Climatology Project (GPCP), National Centers for Environment Protection (NCEP) and the UN Food and Agriculture Organization (FAO). The GPCP data is the preferred measure as it covers the largest number of countries and is most consistent. FAO likewise covers many countries but many years are missing data, hence the approximately 450 data points missing in table 1. The NCEP dataset is only for African nations.

For none of these rainfall measures is growth 0 during the years studied here, suggesting that rainfall has increased over these two decades. The world average growth rates by year is presented in figure 2. The changes year to year are not on average large, and only years 1993 to 1996 showed more than 3 years of growth.

The bottom of table 1 summarizes rainfall by region for the time period discussed here. As with the world averages, region averages of rainfall are positive and range from 1% to 2.6% growth for the years studied here. The standard deviations are similar across regions, except for the other cateogry, which is nearly twice that of other regions.

Additional country data, including data on industrial and agriculture value added growth, per capita GDP and GDP growth, land in agriculture and percent of land irrigated are from the World Bank Development Indicators (WDI) database. Property rights is from the 2008 Index of Economic Freedom collected by the Heritage Foundation. Each country is scored on a scale of 1 to 10 based on the degree to which a country's laws are deemed to protect private property and the likelihood of property appropriation. Measures of property rights from pre-sample time periods 1975 and 1980 are used in order to minimize possible endogeneity problems, though it does not guarantee there are no issues. Because of data limitations on institutional variables, only 85 countries are included in these specifications.

3.2.3 Results

The specification of lag variables can be very important and may significantly affect regression results. Results are presented here for two lags only, though additional lags (up to 5) have been explored, and the results are not affected significantly.

The results from the estimation of equation 2 for all 110 countries are presented in tables 3 to 5[2]. The results for full GPCP sample (table 3, columns 1 to 5),

[2] In addition to the full sample, the effect of rainfall for 104 middle and low income countries, as well as the smaller sample of 85 countries with institutional data, has also been explored, with similar results obtained (results omitted).

Sub-Saharan Africa only (table 3, columns 6 and 7), NCEP rainfall measures (table 4) and FAO rainfall (table 5) are statistically significant and robust across specifications for lagged rainfall growth (positive) and lagged rainfall growth squared (negative). Because of the similarity in results and the better quality of the GPCP measure, only GPCP measures are used in the remainder of this paper.

GPCP rainfall in table 3 for the world is robust for each time period at approximately 0.04 and rainfall squared is robust at -0.03. This relationship is depicted graphically in figure 3. An increase in rainfall leads to an growth of GDP and is maximal at approximately a 70% growth in rainfall, afterwhich an increase in rainfall has a negative marginal effect on GDP growth. If rainfall increases by greater than 135%, it then has a negative effect on GDP growth.

Percent of land in agriculture, percent of irrigated land and an interaction of irrigated land and land in agriculture (IIA) are significant for the specifications in table 9 and affect GDP as would be expected: countries that rely relatively a lot on agriculture and/or have a relatively low amount of land irrigated experience lower economic growth. Controlling for these variables does not affect the baseline results of rainfall, nor does including the previous periods GDP growth, initial GDP in 1979, region, country and country time effects.

Table 6 further explores the effect of GPCP rainfall by region. The Africa only sample from tables 3 columns 6 and 7 and the Africa interaction in table 6 are consistent with the hypothesis that Africa is more affected by rainfall than other regions. Column 5 of table 6 includes the full controls and region, country and country time effects; the Africa interaction is the only interaction that remains robust to the full controls. This suggests that the effect of rainfall on Asia, Latin America and other non-African nations is likely very similar in effect.

While Africa is unique in the size of effect, it is not the only region affected by rainfall. It is though only affected by rainfall linearly in the contemporaneous year, with a non-linear effect showing up in the lagged year.

3.3 Channels of Effects

Rainfall growth can affect different components of GDP in different ways. For instance, by affecting the productivity of certain sectors, rainfall may lead to either a growth or loss to producers in different sectors. Table 8 presents the results of exploring this effect through the growth in agriculture and industrial value added. The results show that there is a significant effect of rainfall growth on the growth rates of both of these components of GDP. These results are consistent with (12) and suggest that these may be important channels for the effect of rainfall. A shock to rainfall therefore has a similar effect on GDP: increasing rainfall has a positive and decreasing effect on value added, but beyond a certain point this relationship is increasing and negative.

The timing of the effect of rainfall is important. Agriculture is impacted at time t, while industrial value added is impacted by rainfall at $t-1$. A possible explanation for this timing is that a shock to agriculture takes time to affect inputs and consumption from the industrial sector, suggesting that consumption effects of rainfall may be a reason why rainfall shocks are important to all economies. Even in economies that rely very little on agriculture, the shock to consumption may be big enough to affect the larger macro-economy.

3.4 Can Institutions Improve Short-Run Adaptation?

Good institutions may be able to decrease the negative effects of agriculture shocks. Assume the probability of a shock to agriculture is p and the expected wealth of a farmer is $E(w)$. With good institutions, such as secure property rights or government regulation, owners of land may be more likely to invest in irrigation and/or diversification of their land through crop choice. As both of these would mean greater cost to producers, wealth may decrease to w'. Depending on cost and likelihood of a shock, if farmers are risk averse they will invest in infrastructure even if $E(w') \leq E(w)$. If they are risk neutral, they will only invest in infrastructure if $E(w') \leq E(w)$. Infrastructure and diversification though have the benefit of decreasing the variance of wealth as a negative shock will have less of an impact. The overall effect on an economy would then be dampened[3].

Looking at equation 3, institutions then have an effect on rainfall shocks by either dampening the effect of the shock, thus making δ small, or increasing the effect of a shock when good institutions are absent, making δ large.

Table 10 presents the results of interacting rainfall with different measures of protection of property rights. High property rights refers to

The importance of property rights is tested by interacting rainfall with a number of property rights measures from out of the sample date range. Columns 1 and 2 of table 10 test an interaction with a high property rights dummy variable from 1980. This specification of high property rights is a rights value above the sample mean of 4.9 and is not significant for any interaction[4]. Interacting with index measures of property rights in 1975 and 1980 obtains significant, though not very robust, results for $Rainfall\ growth_{t-1}$ and $(Rainfall\ growth_{t-2})^2$.

Higher values of property rights decrease the effects of a negative shock to rainfall growth. Countries with better institutions do not eliminate the negative effect of shocks, but they have been able to dampen the effect of shocks. This is of course just one measure of institutions. Local institutions, such as changing infrastructure and incentives of farmers at a more localized level as discussed by

[3]This is similar to arguments put forth by researchers (24) and (1) on the importance of adaption for mitigating the effect of climate change.

[4]The relationship with different measures of high property rights is likewise tested with no significance found.

(24) and (1), may be even more important for mitigating the effect of rainfall shocks.

3.5 Discussion

This paper presents evidence that environmental shocks and climate change likely effect economic growth for a larger set of countries than has previously been explored. Rainfall growth is found to have a non-linear, inverse parabolic relationship on economic growth with the possible channels of this effect being agriculture and industrial value added. Private property rights institutions, as measured through the Heritage database, show some significance in decreasing the impact of these shocks.

Climate change affects rainfall through an increase in variance of rainfall. Thus, rather than increasing or decreasing rainfall evenly, climate change will instead increase the incidence of very low rainfall and very high rainfall years. Previous research that does not take into account the second order effects of rainfall can lead to the incorrect interpretation that increases in rainfall are always good for an economy.

These results suggest that climate change will likely have important implications for all economies, including nations where agriculture is a small part of the economy, and even in the instances where climate change increases the amount of rainfall. Climate change is not likely to be reversed in the near future, though the role of property rights suggests that mitigation of effects may be done at the individual level in countries where property rights are not strong or where irrigation and other infrastructure is weak.

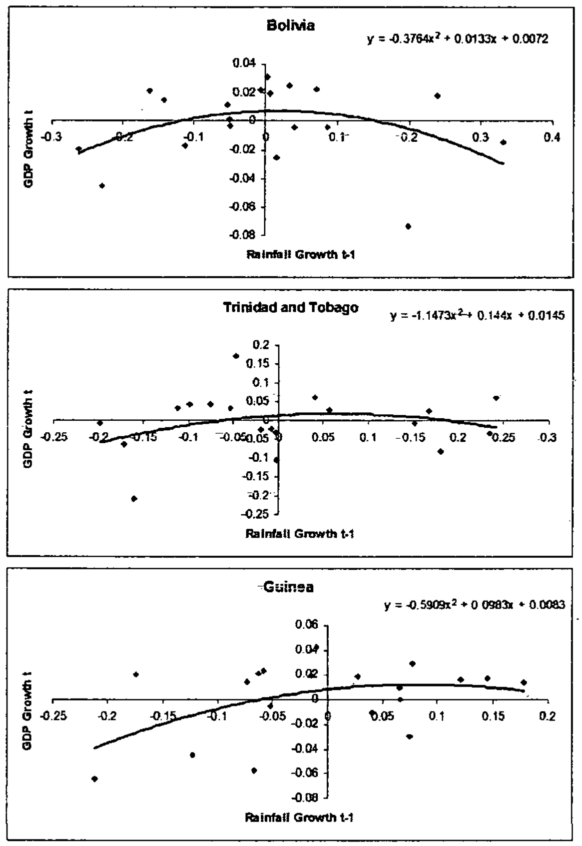

Figure 3.1: Graphical depiction of relationship between GPCP rainfall growth and GDP growth for a selection of countries.

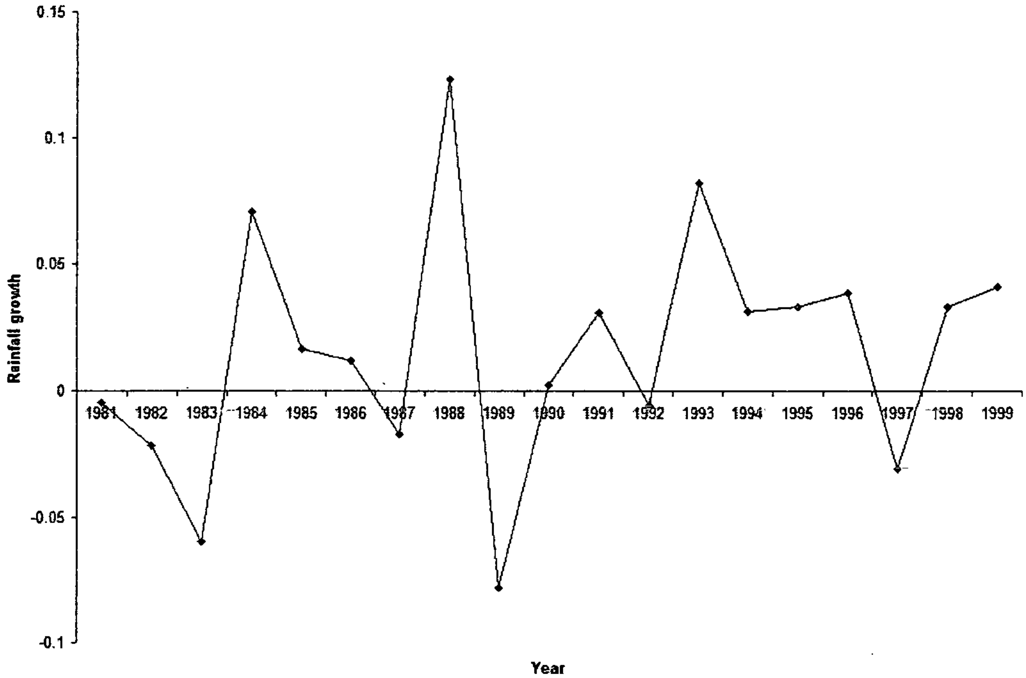

Fig. 3.2: Average world rainfall growth.

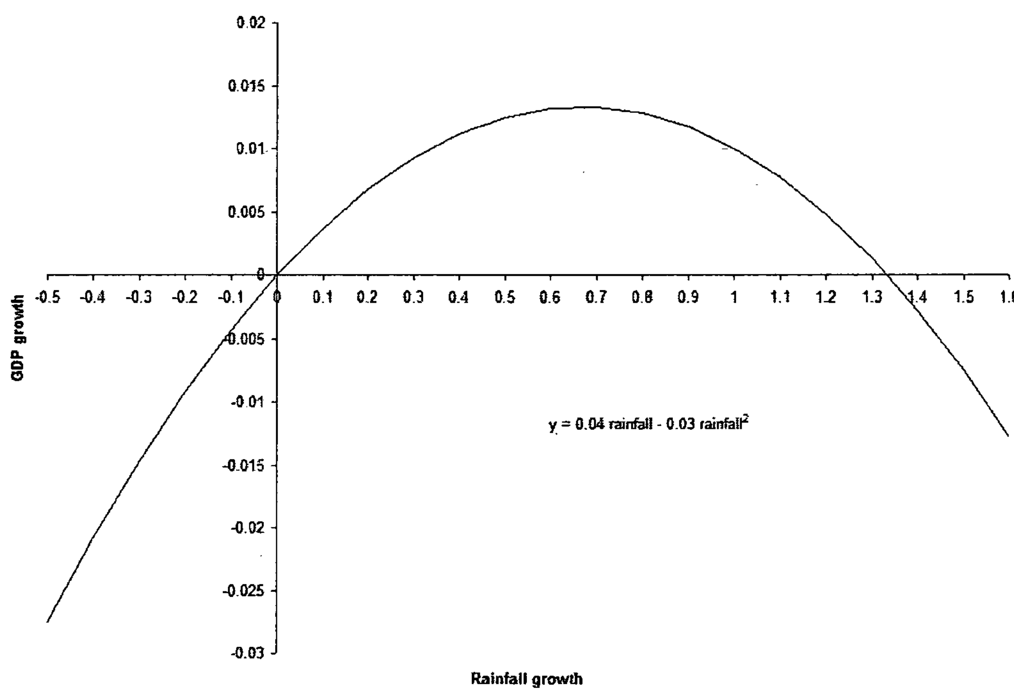

Fig. 3.3: Graphical depiction of relationship between GPCP rainfall growth and GDP growth from table 3, column 5.

Table 3.1: Summary statistics.

Variable	Obs	Mean	Std. Dev.	Min	Max
GPCP Rainfall $growth_t$	2090	0.0157	0.2085	-0.6274	1.3168
GPCP $(Rainfall\ growth_t)^2$	2090	0.0437	0.0991	0.0000	1.7338
FAO Rainfall $growth_t$	1646	0.0912	1.0273	-1	26.3200
FAO $(Rainfall\ growth_t)^2$	1646	1.0631	20.6842	0	692.7424
NCEP Rainfall $growth_t$	665	0.0209	0.2082	-0.4715	1.1479
NCEP $(Rainfall\ growth_t)^2$	665	0.0437	0.0900	0.0000	1.3176
GDP $growth_{t-1}$	2090	0.0083	0.0584	-0.4740	0.6704
Log of per capita GDP in 1979	2090	4.0128	3.9370	0.3160	15.6370
Interaction of irrigated land and land in agriculture	1955	0.3156	0.4649	0	1
Dummy for high percent of land in agriculture	2090	0.5364	0.4988	0	1
Dummy for low percent of land irrigated	2161	0.5863	0.4926	0	1
Agriculture value added growth	1884	0.0261	0.0909	-0.4958	0.7801
Industrial value added growth	1884	0.0339	0.0908	-0.6535	1.2797
Property rights in 1980	1558	4.9585	1.9132	1.8	8.3
Property rights in 1975	874	4.6326	1.7399	1.1	8.3
Dummy for high property rights	1558	0.6098	0.4880	0	1

Rainfall by regions	Obs	Mean	Std. Dev.	Min	Max
Africa	665	0.0166	0.1914	-0.4839	0.8902
Asia	323	0.0149	0.2014	-0.4133	1.0039
Eastern Europe	76	0.0094	0.1912	-0.4000	0.6104
Latin America	418	0.0150	0.1940	-0.3856	1.3168
Western	399	0.0111	0.1520	-0.4966	0.5687
Other	209	0.0263	0.3519	-0.6274	1.1314

Table 3.2: Countries in the sample.

Algeria	Egypt	Kenya	Rwanda
Angola	El Salvador	Lao PDR	Saudi Arabia
Argentina	Ethiopia	Lesotho	Senegal
Australia	Fiji	Madagascar	Sierra Leone
Austria	Finland	Malawi	Singapore
Bangladesh	France	Malaysia	South Africa
Belgium	Gabon	Mali	South Korea
Benin	Gambia	Mauritania	Spain
Bhutan	Germany	Mexico	Sri Lanka
Bolivia	Ghana	Mongolia	Swaziland
Botswana	Greece	Morocco	Sweden
Brazil	Guatemala	Mozambique	Switzerland
Bulgaria	Guinea	Nepal	Syrian Arab Republic
Burkina Faso	Guinea-Bissau	Netherlands	Tanzania
Burundi	Guyana	New Zealand	Thailand
Cameroon	Haiti	Nicaragua	Togo
Canada	Honduras	Niger	Trinidad and Tobago
Central African Republic	Hungary	Nigeria	Tunisia
Chad	India	Norway	Turkey
Chile	Indonesia	Pakistan	Uganda
China	Iran	Panama	United Kingdom
Colombia	Ireland	Papua New Guinea	United States
Dem. Rep. of Congo	Israel	Paraguay	Uruguay
Costa Rica	Italy	Peru	Venezuela
Cyprus	Ivory Coast	Philippines	Zambia
Denmark	Jamaica	Poland	Zimbabwe
Dominican Republic	Japan	Portugal	
Ecuador	Jordan	Romania	

Table 3.3: OLS regression results for GPCP rainfall with economic growth as the dependent variable.

	Full sample					Africa only	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$Rainfall\ growth_t$	0.0394***	0.0354***	0.0391***	0.0361***	0.0414***	0.0867***	0.0862***
	[0.0077]	[0.0079]	[0.0079]	[0.0082]	[0.0082]	[0.0190]	[0.0197]
$Rainfall\ growth_{t-1}$	0.0385***	0.0324***	0.0383***	0.0343***	0.0387***	0.0749***	0.0774***
	[0.0087]	[0.0092]	[0.0093]	[0.0098]	[0.0101]	[0.0266]	[0.0266]
$Rainfall\ growth_{t-2}$	0.0194***	0.0146**	0.0195***	0.0164**	0.0186**	0.0256	0.0277
	[0.0072]	[0.0072]	[0.0074]	[0.0076]	[0.0078]	[0.0221]	[0.0232]
$(Rainfall\ growth_t)^2$	-0.0297**	-0.0335**	-0.0312**	-0.0310**	-0.0340**	-0.0517	-0.0558
	[0.0140]	[0.0151]	[0.0135]	[0.0149]	[0.0154]	[0.0368]	[0.0377]
$(Rainfall\ growth_{t-1})^2$	-0.0249*	-0.0269*	-0.0263*	-0.0248*	-0.0278*	-0.1172**	-0.1205**
	[0.0144]	[0.0162]	[0.0158]	[0.0164]	[0.0169]	[0.0453]	[0.0454]
$(Rainfall\ growth_{t-2})^2$	-0.0064	-0.0095	-0.0088	-0.0097	-0.0111	-0.0056	-0.0139
	[0.0110]	[0.0111]	[0.0103]	[0.0114]	[0.0114]	[0.0288]	[0.0302]
GDP $growth_{t-1}$					0.0194		-0.0408
					[0.0366]		[0.0580]
Log of per capita GDP in 1979					-0.0051***		-0.0035***
					[0.0005]		[0.0008]
IIA					0.0202*		0.0576***
					[0.0108]		[0.0109]
Dummy for high percent of land in agriculture					-0.0577***		-0.0523***
					[0.0031]		[0.0082]
Dummy for low percent of land irrigated					-0.0172***		-0.0188**
					[0.0012]		[0.0071]
Region dummies	no	no	no	yes	yes	no	no
Country fixed effects	no	no	yes	yes	yes	yes	yes
Country time trends	no	yes	no	yes	yes	yes	yes
Observations	1980	1980	1980	1980	1853	630	612
R^2	0.02	0.13	0.14	0.22	0.20	0.16	0.16

[1]Robust standard errors are in parenthesis and are clustered by country. ***, ** and * denote significance at the 99%, 95% and 90% levels respectively. IIA is interaction of irrigated land and land in agriculture.

Table 3.4: OLS regression results for NCEP (Africa only) rainfall with economic growth as the dependent variable and full sample.

	(1)	(2)	(3)	(4)	(5)
$Rainfall\ growth_t$	0.0777***	0.0737***	0.0784***	0.0732***	0.0727***
	[0.0168]	[0.0170]	[0.0169]	[0.0184]	[0.0191]
$Rainfall\ growth_{t-1}$	0.0766***	0.0735***	0.0760***	0.0724***	0.0734***
	[0.0205]	[0.0218]	[0.0208]	[0.0238]	[0.0238]
$Rainfall\ growth_{t-2}$	0.0243	0.0212	0.024	0.0204	0.021
	[0.0182]	[0.0185]	[0.0184]	[0.0191]	[0.0198]
$(Rainfall\ growth_t)^2$	-0.0139	-0.0247	-0.0329	-0.0251	-0.0286
	[0.0246]	[0.0264]	[0.0244]	[0.0241]	[0.0249]
$(Rainfall\ growth_{t-1})^2$	-0.0968***	-0.1080***	-0.1113***	-0.1084***	-0.1098***
	[0.0284]	[0.0290]	[0.0304]	[0.0315]	[0.0316]
$(Rainfall\ growth_{t-2})^2$	0.0255	0.0096	0.0078	0.0064	0.0016
	[0.0267]	[0.0285]	[0.0269]	[0.0286]	[0.0294]
$GDP\ growth_{t-1}$					-0.034
					[0.0576]
Log of per capita GDP in 1979					-0.0038***
					[0.0005]
IIA					0.0452***
					[0.0086]
Dummy for high percent of land in agriculture					-0.0437***
					[0.0073]
Dummy for low percent of land irrigated					-0.005
					[0.0053]
Region dummies	no	no	no	yes	yes
Country fixed effects	no	no	yes	yes	yes
Country time trends	no	yes	no	yes	yes
Observations	630	630	630	630	612
R^2	0.05	0.1	0.09	0.16	0.16

[1]Robust standard errors are in parenthesis and are clustered by country. ***, ** and * denote significance at the 99%, 95% and 90% levels respectively. IIA is interaction of irrigated land and land in agriculture.

Table 3.5: OLS regression results for FAO rainfall with economic growth as the dependent variable and full sample.

	(1)	(2)	(3)	(4)	(5)
Rainfall growth$_t$	0.0091***	0.0099***	0.0102***	0.0117***	0.0122***
	[0.0031]	[0.0032]	[0.0035]	[0.0032]	[0.0033]
Rainfall growth$_{t-1}$	0.0081*	0.0078*	0.0083**	0.0087**	0.0092**
	[0.0044]	[0.0042]	[0.0039]	[0.0037]	[0.0039]
Rainfall growth$_{t-2}$	-0.0008	-0.0022	-0.0012	-0.0001	0.0003
	[0.0035]	[0.0040]	[0.0046]	[0.0047]	[0.0048]
$(Rainfall\ growth_t)^2$	-0.0004***	-0.0004**	-0.0004**	-0.0005***	-0.0005***
	[0.0001]	[0.0001]	[0.0002]	[0.0002]	[0.0002]
$(Rainfall\ growth_{t-1})^2$	-0.0004**	-0.0003*	-0.0003**	-0.0004**	-0.0004**
	[0.0002]	[0.0002]	[0.0001]	[0.0002]	[0.0002]
$(Rainfall\ growth_{t-2})^2$	0	0.0001	0.0001	0	0
	[0.0002]	[0.0002]	[0.0003]	[0.0003]	[0.0003]
GDP growth$_{t-1}$					-0.0011
					[0.0345]
Log of per capita GDP in 1979					-0.0062***
					[0.0004]
IIA					-0.0088
					[0.0108]
Dummy for high percent of land in agriculture					-0.0570***
					[0.0037]
Dummy for low percent of land irrigated					0.0150***
					[0.0023]
Region dummies	no	no	no	yes	yes
Country fixed effects	no	no	yes	yes	yes
Country time trends	no	yes	no	yes	yes
Observations	1629	1629	1629	1629	1522
R^2	0.01	0.13	0.14	0.24	0.23

[1]Robust standard errors are in parenthesis and are clustered by country. ***, ** and * denote significance at the 99%, 95% and 90% levels respectively. IIA is interaction of irrigated land and land in agriculture.

Table 3.6: OLS regression results for GPCP rainfall interacted with region dummies with economic growth as the dependent variable.

	(1)	(2)	(3)	(4)	(5)
Africa x $Rainfall\ growth_t$	0.0814***	0.0790***	0.0754***	0.0669***	0.0654***
	[0.0193]	[0.0202]	[0.0195]	[0.0210]	[0.0213]
Africa x $Rainfall\ growth_{t-1}$	0.0763***	0.0764***	0.0692***	0.0635**	0.0591**
	[0.0237]	[0.0249]	[0.0247]	[0.0273]	[0.0273]
Africa x $Rainfall\ growth_{t-2}$	0.0239	0.0215	0.0144	0.0085	0.0059
	[0.0219]	[0.0215]	[0.0220]	[0.0225]	[0.0234]
Africa x $(Rainfall\ growth_t)^2$	-0.0645	-0.0468	-0.0266	-0.0215	-0.0175
	[0.0396]	[0.0455]	[0.0417]	[0.0457]	[0.0473]
Africa x $(Rainfall\ growth_{t-1})^2$	-0.1532***	-0.1396***	-0.1184**	-0.1194**	-0.1164**
	[0.0408]	[0.0476]	[0.0499]	[0.0497]	[0.0499]
Africa x $(Rainfall\ growth_{t-2})^2$	-0.0149	0.0012	0.0261	0.0227	0.0248
	[0.0345]	[0.0336]	[0.0297]	[0.0313]	[0.0334]
Asia x $Rainfall\ growth_t$	-0.0293	-0.0335	-0.0238	-0.0257	-0.0077
	[0.0209]	[0.0209]	[0.0187]	[0.0194]	[0.0189]
Asia x $Rainfall\ growth_{t-1}$	-0.0061	-0.0077	0.0038	0.003	0.0251
	[0.0223]	[0.0243]	[0.0232]	[0.0243]	[0.0231]
Asia x $Rainfall\ growth_{t-2}$	-0.0407**	-0.0364*	-0.0314	-0.0305	-0.0202
	[0.0189]	[0.0193]	[0.0194]	[0.0205]	[0.0243]
Asia x $(Rainfall\ growth_t)^2$	0.0633*	0.0691*	0.0432	0.0336	0.0384
	[0.0351]	[0.0381]	[0.0386]	[0.0421]	[0.0427]
Asia x $(Rainfall\ growth_{t-1})^2$	0.0479	0.0429	-0.0014	0.0067	-0.0075
	[0.0589]	[0.0697]	[0.0729]	[0.0763]	[0.0908]
Asia x $(Rainfall\ growth_{t-2})^2$	0.1419**	0.1198**	0.0624	0.0642	0.0522
	[0.0544]	[0.0538]	[0.0525]	[0.0568]	[0.0692]
Latin Am x $Rainfall\ growth_t$	0.0369*	0.0332	0.0282	0.0051	0.0033
	[0.0190]	[0.0206]	[0.0215]	[0.0215]	[0.0217]
Latin Am x $Rainfall\ growth_{t-1}$	0.0580**	0.0570**	0.0491*	0.0229	0.0196
	[0.0255]	[0.0271]	[0.0286]	[0.0280]	[0.0280]
Latin Am x $Rainfall\ growth_{t-2}$	0.0161	0.0145	0.0053	-0.0103	-0.0125
	[0.0213]	[0.0219]	[0.0233]	[0.0228]	[0.0228]
Latin Am x $(Rainfall\ growth_t)^2$	-0.0452	-0.02	-0.0044	0.0147	0.0178
	[0.0315]	[0.0346]	[0.0303]	[0.0325]	[0.0334]
Latin Am x $(Rainfall\ growth_{t-1})^2$	-0.0731**	-0.051	-0.0348	-0.016	-0.0125
	[0.0287]	[0.0322]	[0.0315]	[0.0312]	[0.0315]
Latin Am x $(Rainfall\ growth_{t-2})^2$	0.0033	0.0261	0.0439	0.0585	0.0598*
	[0.0235]	[0.0255]	[0.0337]	[0.0357]	[0.0348]
$Rainfall\ growth_t$	0.0156*	0.0123	0.0167*	0.0198**	0.0217**
	[0.0091]	[0.0095]	[0.0088]	[0.0094]	[0.0096]
$Rainfall\ growth_{t-1}$	0.0093	0.0025	0.0098	0.0114	0.0139*
	[0.0071]	[0.0077]	[0.0070]	[0.0070]	[0.0072]
$Rainfall\ growth_{t-2}$	0.0146**	0.0092*	0.0162***	0.0172***	0.0181***
	[0.0057]	[0.0055]	[0.0054]	[0.0051]	[0.0052]
$(Rainfall\ growth_t)^2$	-0.0154	-0.0256	-0.0278	-0.0302	-0.0326
	[0.0247]	[0.0270]	[0.0229]	[0.0274]	[0.0279]
$(Rainfall\ growth_{t-1})^2$	0.0136	0.006	0.0028	0.0022	0.0002
	[0.0181]	[0.0212]	[0.0211]	[0.0213]	[0.0217]
$(Rainfall\ growth_{t-2})^2$	-0.0147	-0.0233*	-0.0261**	-0.0283**	-0.0287**
	[0.0120]	[0.0134]	[0.0114]	[0.0128]	[0.0132]
Additional controls	no	no	no	no	yes
Region dummies	no	no	no	yes	yes
Country fixed effects	no	no	yes	yes	yes
Country time trends	no	yes	no	yes	yes
Observations	1980	1980	1980	1980	1853
R-squared	0.05	0.15	0.16	0.23	0.22

[1]Robust standard errors are in parenthesis and are clustered by country. ***, ** and * denote significance at the 99%, 95% and 90% levels respectively.

Table 3.7: OLS regression results with growth in agriculture and industrial value added as the dependent variables.

	Agriculture Value Added					Industrial Value Added				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Rainfall growth$_t$	0.0817***	0.0840***	0.0846***	0.0859***	0.0928***	0.0312**	0.0310**	0.0321**	0.0317**	0.0396***
	[0.0206]	[0.0217]	[0.0219]	[0.0228]	[0.0230]	[0.0123]	[0.0128]	[0.0129]	[0.0126]	[0.0130]
Rainfall growth$_{t-1}$	0.0550***	0.0572***	0.0575***	0.0620***	0.0691***	0.0578***	0.0559***	0.0575***	0.0583***	0.0635***
	[0.0184]	[0.0190]	[0.0193]	[0.0203]	[0.0217]	[0.0150]	[0.0155]	[0.0154]	[0.0169]	[0.0170]
Rainfall growth$_{t-2}$	0.0247	0.0244	0.0246	0.0271	0.0330*	0.0113	0.0086	0.0088	0.0076	0.0085
	[0.0152]	[0.0157]	[0.0160]	[0.0175]	[0.0185]	[0.0157]	[0.0160]	[0.0161]	[0.0154]	[0.0164]
$(Rainfall\ growth_t)^2$	-0.0241	-0.0314	-0.0425	-0.0359	-0.038	-0.0098	-0.0191	-0.0216	-0.0247	-0.0288
	[0.0400]	[0.0421]	[0.0429]	[0.0443]	[0.0448]	[0.0227]	[0.0226]	[0.0226]	[0.0244]	[0.0249]
$(Rainfall\ growth_{t-1})^2$	0.0101	0.0025	-0.0081	-0.0037	-0.0032	-0.0524**	-0.0595**	-0.0636***	-0.0634**	-0.0668**
	[0.0341]	[0.0361]	[0.0350]	[0.0375]	[0.0382]	[0.0229]	[0.0233]	[0.0231]	[0.0254]	[0.0263]
$(Rainfall\ growth_{t-2})^2$	0.0065	0.0005	-0.0083	-0.0005	-0.0041	0.008	0.0017	0.001	0.0049	0.0064
	[0.0217]	[0.0222]	[0.0232]	[0.0230]	[0.0235]	[0.0247]	[0.0277]	[0.0274]	[0.0282]	[0.0293]
GDP growth$_{t-1}$					-0.1526*					0.1223**
					[0.0858]					[0.0473]
Log of per capita GDP in 1979					-0.0091***					-0.0119***
					[0.0025]					[0.0018]
IIA					-0.0036					-0.012
					[0.0336]					[0.0294]
Dummy for high percent of land in agriculture					0.1963***					0.0005
					[0.0318]					[0.0206]
Dummy for low percent of land irrigated					-0.0367**					0.0117*
					[0.0180]					[0.0064]
Region dummies	no	no	no	yes	yes	no	no	no	yes	yes
Country fixed effects	no	no	yes	yes	yes	no	no	yes	yes	yes
Country time trends	no	yes	no	yes	yes	no	yes	no	yes	yes
Observations	1795	1795	1795	1795	1682	1795	1795	1795	1795	1682
R^2	0.03	0.06	0.06	0.09	0.1	0.01	0.11	0.13	0.19	0.2

[1]Robust standard errors are in parenthesis and are clustered by country. ***, ** and * denote significance at the 99%, 95% and 90% levels respectively. IIA is interaction of irrigated land and land in agriculture.

Table 3.8: OLS regression results with growth in agriculture and industrial value added as the dependent variables.

	Agriculture Value Added					Industrial Value Added				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Africa x *Rainfall growth*$_t$	0.1064**	0.1039*	0.1025*	0.1072*	0.1011*	0.0576*	0.0555*	0.0684**	0.0665**	0.0650**
	[0.0528]	[0.0553]	[0.0566]	[0.0587]	[0.0599]	[0.0319]	[0.0330]	[0.0317]	[0.0311]	[0.0321]
Africa x *Rainfall growth*$_{t-1}$	-0.0047	-0.0062	-0.0054	-0.0041	0.0052	0.0702	0.0704	0.0808*	0.0807*	0.0644
	[0.0518]	[0.0532]	[0.0538]	[0.0567]	[0.0561]	[0.0429]	[0.0442]	[0.0426]	[0.0450]	[0.0454]
Africa x *Rainfall growth*$_{t-2}$	0.0546	0.0571	0.0612	0.0618	0.068	-0.0157	-0.0157	-0.0079	-0.0105	-0.0186
	[0.0428]	[0.0448]	[0.0450]	[0.0488]	[0.0504]	[0.0335]	[0.0347]	[0.0341]	[0.0350]	[0.0363]
Africa x (*Rainfall growth*$_t$)^2	0.0011	-0.0341	0.0087	-0.013	-0.0198	-0.1009	-0.1242*	-0.1645***	-0.1696***	-0.1601**
	[0.1033]	[0.1172]	[0.1202]	[0.1258]	[0.1266]	[0.0608]	[0.0648]	[0.0585]	[0.0617]	[0.0622]
Africa x (*Rainfall growth*$_{t-1}$)^2	-0.0425	-0.0709	-0.0369	-0.0498	-0.051	-0.0243	-0.0516	-0.0833	-0.0816	-0.0852
	[0.1090]	[0.1105]	[0.1073]	[0.1121]	[0.1113]	[0.0491]	[0.0519]	[0.0502]	[0.0520]	[0.0522]
Africa x (*Rainfall growth*$_{t-2}$)^2	-0.0569	-0.0924	-0.0652	-0.0847	-0.1051	0.0745	0.0459	0.0168	0.0257	0.0327
	[0.0550]	[0.0676]	[0.0675]	[0.0706]	[0.0756]	[0.0502]	[0.0579]	[0.0616]	[0.0594]	[0.0615]
Asia x *Rainfall growth*$_t$	-0.0909**	-0.0968**	-0.1001**	-0.0971**	-0.0757	-0.0049	-0.0132	0.0088	0.022	0.0489
	[0.0445]	[0.0452]	[0.0464]	[0.0476]	[0.0491]	[0.0373]	[0.0399]	[0.0366]	[0.0356]	[0.0443]
Asia x *Rainfall growth*$_{t-1}$	-0.0862**	-0.0922**	-0.0948**	-0.0955**	-0.0920**	-0.0271	-0.0298	-0.005	0.0143	0.0692
	[0.0394]	[0.0398]	[0.0404]	[0.0426]	[0.0451]	[0.0405]	[0.0417]	[0.0419]	[0.0519]	[0.0475]
Asia x *Rainfall growth*$_{t-2}$	-0.0335	-0.0408*	-0.0379	-0.0393	-0.0158	-0.1666	-0.1639	-0.1483	-0.1349	-0.1546
	[0.0226]	[0.0231]	[0.0232]	[0.0269]	[0.0315]	[0.1018]	[0.1077]	[0.1042]	[0.0969]	[0.1347]
Asia x (*Rainfall growth*$_t$)^2	0.0426	0.0715	0.1038	0.0846	0.0915	0.021	0.027	-0.0218	-0.0586	-0.0498
	[0.0838]	[0.0915]	[0.0954]	[0.0991]	[0.0975]	[0.0972]	[0.1088]	[0.0850]	[0.0939]	[0.1156]
Asia x (*Rainfall growth*$_{t-1}$)^2	0.037	0.0594	0.0922	0.0716	0.1096	-0.0071	-0.0406	-0.1064	-0.118	-0.1771
	[0.1041]	[0.1111]	[0.1079]	[0.1154]	[0.1222]	[0.1787]	[0.1769]	[0.1943]	[0.2140]	[0.2575]
Asia x (*Rainfall growth*$_{t-2}$)^2	-0.0413	-0.0086	0.0117	-0.0131	-0.033	0.5359*	0.4914	0.4091	0.3836	0.4743
	[0.0622]	[0.0530]	[0.0545]	[0.0525]	[0.0542]	[0.2915]	[0.3213]	[0.3000]	[0.2965]	[0.3911]
Latin Am x *Rainfall growth*$_t$	-0.0898**	-0.0974**	-0.1024**	-0.1122**	-0.1179**	0.0851***	0.0756**	0.0797**	0.0553*	0.0535*
	[0.0451]	[0.0477]	[0.0494]	[0.0518]	[0.0536]	[0.0288]	[0.0312]	[0.0312]	[0.0287]	[0.0293]
Latin Am x *Rainfall growth*$_{t-1}$	-0.046	-0.0547	-0.0578	-0.0745*	-0.0711	0.0567*	0.0484	0.0502	0.0228	0.0159
	[0.0386]	[0.0402]	[0.0407]	[0.0424]	[0.0441]	[0.0339]	[0.0329]	[0.0339]	[0.0373]	[0.0370]
Latin Am x *Rainfall growth*$_{t-2}$	-0.0268	-0.033	-0.0323	-0.0449*	-0.0407	0.0198	0.012	0.0103	-0.0067	-0.0124
	[0.0224]	[0.0229]	[0.0232]	[0.0269]	[0.0284]	[0.0299]	[0.0312]	[0.0327]	[0.0353]	[0.0345]
Latin Am x (*Rainfall growth*$_t$)^2	0.0571	0.0783	0.1215	0.1195	0.1422	-0.1187***	-0.0990**	-0.0980**	-0.0782	-0.0766
	[0.0850]	[0.0915]	[0.0987]	[0.1026]	[0.1016]	[0.0416]	[0.0477]	[0.0476]	[0.0506]	[0.0507]
Latin Am x (*Rainfall growth*$_{t-1}$)^2	-0.0422	-0.018	0.0171	0.0219	0.0234	-0.0736	-0.0587	-0.0544	-0.0333	-0.0299
	[0.0702]	[0.0757]	[0.0692]	[0.0740]	[0.0739]	[0.0535]	[0.0563]	[0.0538]	[0.0577]	[0.0596]
Latin Am x (*Rainfall growth*$_{t-2}$)^2	0.0151	0.0404	0.0656	0.0627	0.065	0.042	0.059	0.0664	0.079	0.0819
	[0.0360]	[0.0379]	[0.0442]	[0.0458]	[0.0419]	[0.0451]	[0.0481]	[0.0549]	[0.0572]	[0.0559]
Rainfall growth$_t$	0.0836**	0.0875**	0.0895**	0.0908**	0.0942**	-0.0009	0.0022	-0.0038	-0.0024	0.0005
	[0.0380]	[0.0396]	[0.0406]	[0.0419]	[0.0426]	[0.0143]	[0.0151]	[0.0147]	[0.0147]	[0.0154]
Rainfall growth$_{t-1}$	0.0801**	0.0843**	0.0842**	0.0913**	0.0912**	0.0279**	0.0283**	0.0232*	0.0240*	0.0276*
	[0.0345]	[0.0357]	[0.0364]	[0.0385]	[0.0407]	[0.0130]	[0.0140]	[0.0134]	[0.0140]	[0.0143]
Rainfall growth$_{t-2}$	0.0227	0.0235	0.0202	0.0254	0.0248	0.0269**	0.0262**	0.0236**	0.0239**	0.0252**
	[0.0192]	[0.0200]	[0.0203]	[0.0244]	[0.0252]	[0.0111]	[0.0116]	[0.0113]	[0.0115]	[0.0118]
(*Rainfall growth*$_t$)^2	-0.0432	-0.05	-0.0859	-0.0708	-0.0768	0.0415	0.0337	0.0443	0.047	0.0442
	[0.0799]	[0.0843]	[0.0890]	[0.0909]	[0.0908]	[0.0349]	[0.0413]	[0.0389]	[0.0417]	[0.0414]
(*Rainfall growth*$_{t-1}$)^2	0.0267	0.0188	-0.0107	-0.0013	-0.0007	-0.0381*	-0.0405	-0.0324	-0.0297	-0.0298
	[0.0672]	[0.0724]	[0.0674]	[0.0723]	[0.0728]	[0.0226]	[0.0264]	[0.0247]	[0.0269]	[0.0279]
(*Rainfall growth*$_{t-2}$)^2	0.0241	0.0182	-0.0022	0.0141	0.0137	-0.0498***	-0.0539***	-0.0468***	-0.0437**	-0.0431**
	[0.0306]	[0.0320]	[0.0347]	[0.0349]	[0.0347]	[0.0148]	[0.0164]	[0.0151]	[0.0170]	[0.0183]
Region dummies	no	no	no	yes	yes	no	no	no	yes	yes
Country fixed effects	no	no	yes	yes	yes	no	no	yes	yes	yes
Country time trends	no	yes	no	yes	yes	no	yes	no	yes	yes
Observations	1795	1795	1795	1795	1682	1795	1795	1795	1795	1682
R^2	0.05	0.09	0.09	0.12	0.12	0.04	0.13	0.15	0.21	0.22

[1] Robust standard errors are in parenthesis and are clustered by country. ***, ** and * denote significance at the 99%, 95% and 90% levels respectively. IIA is interaction of irrigated land and land in agriculture.

Table 3.9: OLS regression results for GPCP rainfall interacted with percent of land irrigated and percent of land in agriculture with economic growth as the dependent variable.

	(1)	(2)	(3)	(4)	(5)
Irrigated land in agriculture x $Rainfall\ growth_t$	0.0193	0.0207	0.0262	0.0253	0.0249
	[0.0176]	[0.0179]	[0.0181]	[0.0193]	[0.0192]
Irrigated land in agriculture x $Rainfall\ growth_{t-1}$	0.0507**	0.0532**	0.0565**	0.0568**	0.0563**
	[0.0243]	[0.0254]	[0.0246]	[0.0275]	[0.0271]
Irrigated land in agriculture x $Rainfall\ growth_{t-2}$	0.0137	0.015	0.0153	0.0154	0.0147
	[0.0176]	[0.0173]	[0.0176]	[0.0180]	[0.0179]
Irrigated land in agriculture x $(Rainfall\ growth_t)^2$	0.0055	-0.0043	-0.0273	-0.0262	-0.0255
	[0.0277]	[0.0284]	[0.0256]	[0.0285]	[0.0283]
Irrigated land in agriculture x $(Rainfall\ growth_{t-1})^2$	-0.0376	-0.0526	-0.0687*	-0.0708*	-0.0703*
	[0.0309]	[0.0367]	[0.0372]	[0.0395]	[0.0391]
Irrigated land in agriculture x $(Rainfall\ growth_{t-2})^2$	0.0281	0.011	0.0018	0.0034	0.0049
	[0.0240]	[0.0203]	[0.0188]	[0.0208]	[0.0215]
$Rainfall\ growth_t$	0.0405***	0.0362***	0.0374***	0.0347***	0.0350***
	[0.0093]	[0.0092]	[0.0092]	[0.0094]	[0.0094]
$Rainfall\ growth_{t-1}$	0.0306***	0.0249***	0.0283***	0.0239**	0.0234**
	[0.0089]	[0.0093]	[0.0094]	[0.0093]	[0.0096]
$Rainfall\ growth_{t-2}$	0.0188**	0.0144*	0.0188**	0.0153*	0.0150*
	[0.0082]	[0.0086]	[0.0087]	[0.0089]	[0.0089]
$(Rainfall\ growth_t)^2$	-0.0408*	-0.0368	-0.0253	-0.0276	-0.0278
	[0.0208]	[0.0224]	[0.0195]	[0.0218]	[0.0218]
$(Rainfall\ growth_{t-1})^2$	-0.0222	-0.015	-0.0077	-0.0061	-0.0055
	[0.0186]	[0.0211]	[0.0200]	[0.0206]	[0.0208]
$(Rainfall\ growth_{t-2})^2$	-0.0215	-0.0154	-0.0115	-0.0139	-0.0139
	[0.0134]	[0.0144]	[0.0133]	[0.0153]	[0.0154]
IIA	0.0003	0.0023	-0.0165	-0.0288**	0.0280**
	[0.0067]	[0.0150]	[0.0121]	[0.0130]	[0.0129]
Dummy for high percent of land in agriculture	-0.0036	-0.0083	-0.0022	-0.0079	-0.0718***
	[0.0057]	[0.0137]	[0.0118]	[0.0059]	[0.0050]
Dummy for low percent of land irrigated	-0.0161***	-0.0176	0.0046	-0.0167***	-0.0166***
	[0.0049]	[0.0111]	[0.0040]	[0.0021]	[0.0021]
$GDP\ growth_{t-1}$					0.0178
					[0.0364]
Log of per capita GDP in 1979					-0.0069***
					[0.0003]
Region dummies	no	no	no	yes	yes
Country fixed effects	no	no	yes	yes	yes
Country time trends	no	yes	no	yes	yes
Observations	1853	1853	1853	1853	1853
R^2	0.05	0.13	0.13	0.21	0.21

[1] Robust standard errors are in parenthesis and are clustered by country. ***, ** and * denote significance at the 99%, 95% and 90% levels respectively. IIA is interaction of irrigated land and land in agriculture.

Table 3.10: OLS regression results for GPCP rainfall interacted with property rights score with economic growth as the dependent variable.

	(1)	(2)	(3)	(4)	(5)	(6)
High property rights 1980 dummy x $Rainfall\ growth_t$	0.0125	0.0113				
	[0.0185]	[0.0191]				
High property rights 1980 dummy x $Rainfall\ growth_{t-1}$	-0.0137	-0.0186				
	[0.0166]	[0.0172]				
High property rights 1980 dummy x $Rainfall\ growth_{t-2}$	-0.0182	-0.019				
	[0.0132]	[0.0149]				
High property rights 1980 dummy x $(Rainfall\ growth_t)^2$	0.002	0.0016				
	[0.0192]	[0.0227]				
High property rights 1980 dummy x $(Rainfall\ growth_{t-1})^2$	-0.0035	-0.0082				
	[0.0222]	[0.0191]				
High property rights 1980 dummy x $(Rainfall\ growth_{t-2})^2$	-0.0085	-0.0123				
	[0.0155]	[0.0146]				
High property rights 1980 dummy	0.0146***	0.1619*				
	[0.0037]	[0.0863]				
Property rights in 1975 x $Rainfall\ growth_t$			-0.0028	-0.0034		
			[0.0044]	[0.0053]		
Property rights in 1975 x $Rainfall\ growth_{t-1}$			-0.0119**	-0.0110**		
			[0.0054]	[0.0054]		
Property rights in 1975 x $Rainfall\ growth_{t-2}$			-0.0033	-0.002		
			[0.0042]	[0.0043]		
Property rights in 1975 x $(Rainfall\ growth_t)^2$			-0.0046	-0.0046		
			[0.0084]	[0.0097]		
Property rights in 1975 x $(Rainfall\ growth_{t-1})^2$			0.0121	0.0087		
			[0.0112]	[0.0132]		
Property rights in 1975 x $(Rainfall\ growth_{t-2})^2$			-0.0111**	-0.0112**		
			[0.0042]	[0.0048]		
Property rights in 1975			0.0023	0.022		
			[0.0014]	[0.0147]		
Property rights in 1980 x $Rainfall\ growth_t$					0.0007	0.0008
					[0.0041]	[0.0045]
Property rights in 1980 x $Rainfall\ growth_{t-1}$					-0.0033	-0.0047
					[0.0034]	[0.0032]
Property rights in 1980 x $Rainfall\ growth_{t-2}$					-0.0037	-0.0047
					[0.0026]	[0.0032]
Property rights in 1980 x $(Rainfall\ growth_t)^2$					0.0078	0.0028
					[0.0055]	[0.0064]
Property rights in 1980 x $(Rainfall\ growth_{t-1})^2$					0.0003	-0.0064
					[0.0064]	[0.0051]
Property rights in 1980 x $(Rainfall\ growth_{t-2})^2$					-0.0033	-0.0054*
					[0.0035]	[0.0032]
Property rights in 1980					0.0047***	0.0150*
					[0.0008]	[0.0078]
$Rainfall\ growth_t$	0.0159	0.0189*	0.0256	0.0359	0.0171	0.0206
	[0.0118]	[0.0111]	[0.0248]	[0.0289]	[0.0203]	[0.0204]
$Rainfall\ growth_{t-1}$	0.0341***	0.0372***	0.0829***	0.0831***	0.0419**	0.0493***
	[0.0114]	[0.0100]	[0.0306]	[0.0294]	[0.0182]	[0.0155]
$Rainfall\ growth_{t-2}$	0.0318***	0.0303***	0.0367	0.0289	0.0399***	0.0414**
	[0.0089]	[0.0105]	[0.0238]	[0.0239]	[0.0142]	[0.0171]
$(Rainfall\ growth_t)^2$	-0.0055**	-0.0036	0.0292	0.016	-0.0223*	-0.0101
	[0.0025]	[0.0025]	[0.0405]	[0.0506]	[0.0115]	[0.0137]
$(Rainfall\ growth_{t-1})^2$	-0.0075***	-0.0060***	-0.0806	-0.0781	-0.008	0.0071
	[0.0024]	[0.0021]	[0.0505]	[0.0557]	[0.0132]	[0.0102]
$(Rainfall\ growth_{t-2})^2$	-0.0063***	-0.0041*	0.0405	0.0418	0.001	0.0073
	[0.0019]	[0.0022]	[0.0242]	[0.0286]	[0.0075]	[0.0066]
Additional controls	no	yes	no	yes	no	yes
Observations	1520	1423	828	738	1520	1423
R^2	0.040	0.160	0.030	0.200	0.050	0.150

[1] Robust standard errors are in parenthesis and are clustered by country. ***, ** and * denote significance at the 99%, 95% and 90% levels respectively.

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