A Reexamination of Inflation and Growth

Benjamin Lidofsky*

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Abstract

I rely on the empirical model created by Pollin and Zhu (2006) to examine the relationship between inflation and growth beyond the short-term. I replicate their set of countries and extend the period of time examined to 1961-2010. I cannot duplicate their results and find that extensive data revisions may be a key reason for the discrepancy. I test slight adjustments of their model to reduce omitted variable bias. The enhanced model can be directly compared with the empirical work of Mankiw, Romer, and Weil (1992), allowing a contrast of my findings with one of the literature's foundations. The combination of the Pollin and Zhu and Mankiw, Romer, and Weil empirical models leads to increased explanatory power and more reliable estimates. From the combined model, there are indications of significant impacts of inflation on growth in the medium-term (over five years), but negligible impacts over the long-term (twenty-five years). This is most evident in highly developed countries; the relationship between inflation and growth in less developed countries is less clear.

1 Introduction

The 2007 financial crisis and subsequent global recession have increased the interest in determining what makes economies grow. Over the past few years, fiscal policymakers have debated the relative merits of Keynesian stimulus versus austerity, while monetary policymakers have similarly considered the benefits of low interest rate environments over stable

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prices. There are two main points of contention across these debates: are stimulative policies actually effective in rebalancing the economy and are the inflationary risks associated with those measures so costly that they nullify any potential benefits? Particularly regarding monetary policy, this latter question has become increasingly critical as economies experience stronger recoveries. To seek to answer either of these questions with one study is to ask a lot of the data. This study takes a more focused approach and examines the relationship between inflation and growth over the medium- and long-term.

The remainder of this paper is divided into five sections. Section 2 provides a summary of the literature, Section 3 describes the methodology, Section 4 examines the results, Section 5 discusses the implications of the findings, and Section 6 concludes.

2 Literature Review

This section examines two topics: general growth models and empirical studies on the relationship between inflation and growth.

2.1 Growth Models

The Solow (1956) growth model represents one of the foundational components of neoclassical economics. It expands the Harrod-Domar model by relaxing the assumption that factors of production are used in fixed proportions. Instead, Solow allows for labor and capital to be substituted for one another. This stabilizes the equilibrium condition for long-term growth, which was previously precariously balanced on a "knife-edge," as Solow characterizes it. In the Harrod-Domar model, even slight deviations in the components of growth (such as an increase in the savings rate) lead to an unstable path for per capita income. With Solow's model, steady-state per capita output is determined by the economy-wide savings rate and the growth rate of population, both of which are exogenously given. A higher savings rate, ceteris paribus,[1] means that investment is higher, leading to an increase in the level of capital, which boosts output in the steady state. Conversely, faster population growth, ceteris paribus, lowers the stock of capital per worker, making labor less productive. This undermines growth in the steady state.

As an extension to his basic model, Solow also incorporates exogenous technological change into the framework. Technology enhances the productivity of capital or labor, thereby leading to higher levels of output. While Solow notes that there are numerous ways in which technology can be introduced into his model, he focuses on exogenous, neutral changes in technology, which act as a simple multiplier to the initial output of capital and labor. Assuming a Cobb-Douglas production function,[2] in which there are diminishing marginal returns on factors of production, the Solow steady state level of per capita output can be characterized by

$$ln[\frac{Y(t)}{L(t)}] = lnA(0) + gt + \frac{\alpha}{1-\alpha}ln(s) - \frac{\alpha}{1-\alpha}ln(n+g+\delta) \tag{1}$$

where $Y(t)$ is the level of output at time t, $L(t)$ is the stock of labor at time t, $A(0)$ is the initial stock of technology, g is the growth rate of technology, α is the marginal return on capital, s is the savings rate, n is the rate of population growth, and δ is the rate of capital depreciation.

Mankiw, Romer, and Weil (1992) expand on Solow's (1956) model by factoring in human capital, a broad term that includes workers' education, experience, and other forms of

[1] Latin for "all else equal," meaning that only the variable in question changes value.

[2] The Solow model itself is general enough to allow for other specifications. However, it is convenient to focus specifically on the Cobb-Douglas function here, as it is particularly relevant to the later discussion of Mankiw, Romer, and Weil (1992).

knowledge. They note that human capital has long held a predominant role in economic theory and that its exclusion may bias the estimated parameters of the other variables in empirical replications of the Solow model. To support their belief, Mankiw, Romer, and Weil observe that the majority of capital stock in the United States was in the form of human, rather than physical, capital in 1969 (Kendrick, 1976, via Mankiw, Romer, and Weil, 1992). As such, the inclusion of human capital to the model may lead to important adjustments to the original Solow model. Mankiw, Romer, and Weil introduce human capital to the theoretical model by including it as a factor of production. The model is now represented by

$$Y(t) = K(t)^{\alpha} H(t)^{\beta} [A(t)L(t)]^{1-\alpha-\beta} \tag{2}$$

where $K(t)$ is the stock of physical capital at time t, $H(t)$ is the stock of human capital at time t, and β represents the marginal return on human capital. Including human capital yields the following equation for per capita output in the steady state

$$ln[\frac{Y(t)}{L(t)}] = lnA(0) + gt - \frac{\alpha+\beta}{1-\alpha-\beta} ln(n+g+\delta) + \frac{\alpha}{1-\alpha-\beta} ln(s_k) + \frac{\beta}{1-\alpha-\beta} ln(s_h) \tag{3}$$

where s_k represents the share of income invested in physical capital and s_h represents the share of income invested in human capital.

In their 1992 study, Mankiw, Romer, and Weil also run regressions on a sample of countries to determine the effectiveness of their augmented Solow model. Their dependent variable is the log difference in output per working-age person from 1960 to 1985 (i.e., the difference between the values in the two years, not the average annual growth rate during the period). In their representation of the Solow (1956) model, the initial log level of gross domestic product (GDP) is used to approximate the initial stock of technology, $lnA(0)$ (from equation 3) and the logged savings rate accounts for $ln(s_k)$. Depreciation and technological change are assumed to be constant across countries and time, so these assumed values are added to the population growth rate and the log value of this is taken, which incorporates $ln(n + g + \delta)$ into the regressions. They find that the inclusion of a proxy variable for human capital ($ln(s_h)$ in equation 3)–the log value of the average share of the working age population attending secondary school–significantly enhances the overall descriptive power of their regression model and alters the coefficients on all of the other variables. This suggests that Mankiw, Romer, and Weil had eliminated some omitted variable bias. The initial presence of omitted variable bias may explain why, in their regressions to test the original Solow model, Mankiw's, Romer's, and Weil's calculated parameters do not support what the theoretical model would suggest. However, with the inclusion of the human capital proxy, the other coefficients are more consistent with the theoretical model.

As theirs is an augmented version of the Solow model, the conclusions of Mankiw, Romer, and Weil (1992) do not wholly confirm Solow's findings. For example, Mankiw, Romer, and Weil find that the savings rate plays a more significant role in determining the level of per capita output in the steady state than previously thought and that the inclusion of human capital makes the growth rate of population more significant. In particular, given a higher population growth rate, the stock of human capital must be distributed across more workers, which, in turn, lowers labor productivity. This is similar to population growth's impact on the distribution of physical capital across the labor force. An additional finding of the 1992 study is that the augmented Solow model estimates that it takes an economy roughly twice as long to achieve half of its steady state as the original Solow model would suggest.

Both the initial and augmented Solow models, as is common in exogenous growth theory, focus on the economy at the steady state. As used in Solow (1956) and in Mankiw, Romer, and Weil (1992), the steady state refers to the environment in which per capita output does not change over time, as capital per worker becomes constant. The overall stock of capital increases, but only to keep up with population growth and depreciation. Given Keynes' famed quote of how, in the long run, we are all dead, the relevance of the steady state to the present-day economy may be questioned. Further, other growth models have found that an economy can grow in perpetuity without reaching a steady state.

Endogenous growth theorists, for example, believe that the returns on factors of production do not necessarily need to be diminishing and, therefore, an economy can expand indefinitely. Such theories tend to "aggregate up" from microeconomic behavior, which contrasts from Solow's examination of broad, exogenously determined characteristics. For example, Lucas (1988) establishes a learning-by-doing model in which a country's initial level of capital is a key determinant of its long-term growth. Bernanke and Gürkaynak (2002) find the empirical framework of Mankiw, Romer, and Weil (1992) to be sufficiently flexible to test various theoretical growth models and their results suggest that there is some endogeneity in growth. Bernanke's and Gürkaynak's ability to use the Mankiw, Romer, and Weil regression model to examine various conceptions of growth suggests that the model may be of use for this study, as well.

Implicit in the models above is the belief that, at equilibrium, the economy is operating at full capacity. This is a hallmark of classical and neoclassical economics; economies achieve equilibrium at one level of output. Keynesian theory relaxes this assumption and allows for involuntary unemployment to be a persistent trait of the economy. Involuntary unemployment occurs when there is insufficient demand for employees McConnell, Brue, and Flynn (2012). Such unemployment may be inelastic relative to wages, meaning that normal market forces cannot effectively bring the economy back to full employment output. The implications of this are that prolonged stagnation may occur, undermining the economy's trajectory towards the steady-state.

Unlike Solow (1956) and other neoclassical models, Keynesian economics focuses on investment spending, rather than on savings, as a key determinant of growth. Keynes believed that investment was one of the most unreliable components of growth (Meltzer, 1988). In particular, it was very unlikely for there to be equilibrium in the loanable funds market. The reasons for this are largely due to Keynes' reliance on future expectations as a determinant of the level of investment. Not all income has to be consumed or saved; some of it can be hoarded for what Keynes (1937) refers to as liquidity-preference. Economic agents do not have perfect information; the future is, at least to a certain extent, uncertain. Liquidity-preference provides insurance against this uncertainty. However, this hoarded money cannot be used for investment, which undermines growth.

Liquidity-preference is not the only way in which uncertainty enters the loanable funds market. Investment is directly impacted as well. In addition to the future being inherently difficult to predict, another form of risk highlighted by Keynes is the potential for losses due to the failure of an investment project (Meltzer, 1988). Businesses must consider future revenues in order to properly determine whether they should invest; the more ambitious the project, the more certain the firm must be in order to be willing to invest. Expectations of future trends are likely to be based on current conditions; as such, investment spending tends to be diminished during economic contractions. This undermines the economy's ability to return to full employment equilibrium.

This is where one of the quintessential aspects of Keynesian economics, a key role for the government, becomes prominent. The government does not need to make its investment or spending decisions based on expectations of the future; it can act counter-cyclically. When the private sector curbs its spending due to pessimism regarding the future, the government can step in to counter this. Ideally, this can help the economy both maintain equilibrium and operate at full employment output. However, it presumes that the government is able to calculate the precise amount of spending needed to obtain this level of output. Friedman

(1968), among others, has provided numerous reasons why this does not happen in practice. Friedman, for example, has observed that policymakers have a tendency to not wait for their stimulus to take effect. As a result, they often employ additional rounds of stimulus in order to achieve the desired effect. This over-stimulus undermines the economy's ability to recover by excessively growing the money base and crowding out private investment.

Another downside of the Keynesian approach is that it does not have a testable model for the economy. While Solow (1956) is able to distill the steady-state economy into a handful of equations, Keynes has nothing comparable. This makes it difficult to test the implications of Keynesian theory to the same extent that Mankiw, Romer, and Weil (1992) were able to do with the Solow model. To account for this, many researchers have used Keynesian economics as a guide rather than as a formula, per se. Keynes presents numerous reasons why an economy may not operate at full employment output. Researchers can include a variety of variables to proxy Keynes' reasons.

I have taken the time here to briefly discuss these different approaches, as I believe it is critical to understand the underpinning theories that determine the empirical models used in the literature. The variables, time frames, and countries employed should all reflect different aspects of the theoretical literature on growth. In particular, an empirical model based on neoclassical growth theory makes different assumptions than a model informed by Keynesian theory. It is important to be able to recognize these assumptions.

2.2 Empirical Studies Regarding Inflation and Growth

One of the persistent traits to come from the empirical literature on inflation and growth is that the two variables appear to have a nonlinear relationship. In general, extreme rates of inflation have been found to have the most detrimental impacts on growth. The primary question posed by the literature is whether the relationship is significant across all levels of inflation. Is there a range of inflation rates at which inflation is "costless" to growth? The point at which the relationship between inflation and growth becomes significant is referred to as the threshold.

This discussion will largely concentrate on panel studies running linear regressions, though some analyses have used other methods, such as the instrumented variables approach taken by Vaona (2012). Overall, the results have been mixed. Gordon (2011) notes that the inflation-growth relationship may vary over time; studies of the period between 1973 and 1981 suggest that supply shocks played a predominant role. In particular, price-inelastic demand for goods and services allowed for shocks to impact the price level over the short-term. Bruno (1995) comes to a similar conclusion, noting a positive association between inflation and growth during the 1960s, but a negative one in subsequent decades. Additionally, Ball and Mankiw (1995) suggest that relative price changes may have more significant impacts on growth than do aggregate price changes.

Bruno and Easterly (1998) and Motley (1998) find that when the length of the time period examined is expanded, the statistical significance of the relationship between inflation and growth tends to weaken. However, Andrés and Hernando (1999) determine that a long-term, negative relationship exists across all levels of inflation. Other studies estimate the threshold of significance to be quite low; Ghosh and Phillips (1998), for example, calculate a rate around 2.5 percent. However, other studies find the threshold to be around 10 percent (e.g., Judson and Orphanides, 1999; Burdekin et al., 2004). Burdekin et al. (2004) raise concerns over whether some threshold estimates may be biased by not properly accounting for multiple breaks in the inflation-growth relationship; their study finds evidence that as many as four exist. Some studies, such as Fischer (1993), have not focused on determining a threshold, but a turning point–the growth-maximizing rate of inflation. A caveat to the precision of these findings comes from Bruno and Easterly (1998), who find that outlier observations, particularly cases of hyperinflation, are the predominant determinant of their findings.

An additional focus of this branch of the literature has been on examining countries of varying levels of economic development. Studies that focus solely on countries with highly developed economies tend to find a significant, negative association between inflation and growth (e.g., Andrés and Hernando, 1999). When a broader spectrum of countries is examined, though, the significance diminishes (e.g., Barro, 1996; Pollin and Zhu, 2006). Burdekin et al. (2004) suggest, however, that examining countries at various levels of development at the same time may lead to spurious results. When countries are examined separately by level of development, less developed countries seem to have higher inflationary thresholds than more developed countries (e.g., Pollin and Zhu, 2006). This suggests that developing countries can tolerate a higher level of inflation without undermining their growth.

3 Methodology

This section contains four parts. First, the hypothesis is stated and briefly discussed. Next, the statistical framework used to examine the data is described. The variables chosen for the model are then detailed. Lastly, concerns of the validity of the model are discussed.

3.1 Hypothesis

This study tests for the presence of a statistically significant relationship between inflation and output growth over time, with a particular emphasis on longer trends. In particular, this relationship is anticipated to be nonlinear and associated with a non-negative growth-maximizing rate of inflation. It is further assumed that, as longer periods of time are examined, the relationship between inflation and growth will diminish in significance. Joint hypothesis tests will determine if the inflation variables included all have true coefficients of zero. Further, it may be possible to make inferences on the growth-maximizing rate of inflation if the inflation variables are statistically significant.

3.2 Statistical Framework

The methodology of this paper is linear regression. Following Pollin and Zhu (2006), I use two separate specifications for the regression model: ordinary least squares (OLS) and fixed effects (FE). Regression analysis seeks to find an intercept and set of slope coefficients that minimizes the sum of squared error from the data to the estimated regression plane. Algebraically, this is represented as

$$\hat{Y}_i = \hat{\beta}_0 + \hat{\beta}' \underline{X_i} \tag{4}$$

where $\hat{Y}_i$ represents the estimated value of the dependent variable, Y_i for the i^{th} observation, $\hat{\beta}_0$ represents the constant, $\underline{\hat{\beta}}$ represents the estimated vector of coefficients associated with $\underline{X_i}$, the vector of independent variables whose values correspond to the i^{th} observation. The true vector of coefficients is $\underline{\beta}$. The OLS regression determines the linear combination that minimizes the sum of the squared distance between $\hat{Y}_i$ and Y_i. The Gauss-Markov theorem states that, based on assumptions discussed below, OLS estimates have the least variance of all possible linear estimates of Y (Stock and Watson, 2011). For this reason, the use of OLS and associated regression forms provides the best linear approximation of the true relationships between the independent variables and the dependent variable.

In using OLS regressions, several assumptions about the data must be made. In particular,

- Independent variables are fixed in repeated samples and are uncorrelated with the error term.
- The expected value of the error is zero and has finite kurtosis. This also implies that the expected value of the estimate of the dependent variable is the true value of the dependent variable.
- The errors are independently and identically distributed between different observations. Lind, Marchal, and Wathen (2008) note that this assumption may not hold for time series analysis, which is of particular concern to this study.

An additional assumption often made with OLS regressions is that the error is homoskedastically distributed–that is, the distribution of the error is not expected to vary based on the level of the dependent variable. If this is not the case, and the error is heteroskediastically distributed, it is inappropriate to use conventional standard errors. Stock and Watson (2011) recommend the use of clustered standard errors when using panel data, as this specification is able to account for both heteroskedasticity and serial correlation in the error. In particular, clustered standard errors control for potential correlations within groups (Baum, 2006). Here, standard errors will be clustered about countries.

As this study uses panel data, alternative regression models can also be used. Panel data, or pooled cross sectional times series, are used to track the same entities (e.g., countries) across time (e.g., years). This structure allows for the mitigation of potential bias caused by variables outside of the set of independent variables. If such variables are correlated with both the dependent variable and one of the control variables, the control variable has omitted variable bias. This bias makes the estimated coefficient of the control variable unreliable, as it is skewed by the exclusion of the omitted variables. To minimize potential sources of omitted variable bias, three different strategies are undertaken. First, time period dummy variables are included in all regressions, as done in Pollin and Zhu (2006). These dummy variables are able to account for potential omitted variables that are constant across entities, but vary over time. Additionally, like Pollin and Zhu (2006), regressions are estimated both with OLS and with fixed effects (FE). FE regressions control for omitted variables that vary across entities, but are constant over time. The FE regression model is described in detail below. The last way in which omitted variable bias is countered is by critically examining the independent variables used and determining if alterations may be made to reduce the risk of such bias. While omitted variable bias may affect any of the independent variables, the particular concern here is on how the bias may impact the inflation coefficients.

FE regressions assume that there are inherent characteristics of the individual entities in the dataset, which are not fully explained away by the set of independent variables. These characteristics are assumed to be constant over time and uncorrelated across entities. If these characteristics are not accounted for, the variables in the model have omitted variable bias. Notationally, these characteristics can be defined as the variable Z, where z_i represents the characteristics of the i^{th} entity. It is assumed that Z and the independent variables are correlated. To mitigate this bias, the FE regression includes the parameter α, which is equal to $\beta_0 + Z$. Each element of α, α_i will pick up all constant terms of the regression, in particular the characteristics inherent of the i^{th} entity. Algebraically, this yields

$$\hat{Y_{it}} = \underline{\hat{\beta}}' \underline{X} + \alpha_i + u_{it} \tag{5}$$

where i indexes across entities, t indexes across time, and u_{it} is the residual associated with the particular observation. While the FE regression model is an improvement over OLS in its ability to control for these omitted variables, the manner in which it does this combines all constant terms in the regression. This prevents the inclusion of independent variables that are constant over time; variables which may be of interest in their own right (e.g., the initial level of GDP in the Mankiw, Romer, and Weil (1992) empirical Solow model). For this reason, both OLS and FE regressions are used in this study.

3.3 Variables

Pollin and Zhu (2006) rely on panel data for 80 countries from 1961 to 2000. They run two sets of regressions, one on annual data to test for short-term effects, and one on five-year averages to test for medium-term effects.[3] Observations where the population is less than two million are excluded, based on the belief that those economies are not large enough to behave in a conventional manner (Pollin and Zhu, 2006). As the literature discussed above supports the assumption that the relationship between inflation and growth is nonlinear, Pollin and Zhu introduce two forms of nonlinearity into their model. First, observations where the inflation rate was greater than 40 percent are excluded from the dataset. This is in keeping with the results of Bruno and Easterly (1998), who found that their findings were being biased by outlier observations. Additionally, in order to determine whether nonlinearities are present below this 40 percent ceiling on inflation, the squared term of the inflation rate is included as an explanatory variable. This permits the turning point, the inflation rate that maximizes the output growth rate, to be calculated. The turning

[3] Pollin and Zhu (2006) refer to the five-year average regressions as long-term effects, but this paper will refer to them as medium-term effects so as to distinguish them from the twenty-five year averages used in Mankiw, Romer, and Weil (1992).

point is calculated by taking the partial derivative of growth with respect to the inflation rate, and solving for the inflation rate. This results in the following:

$$\text{Turning Point} = -\frac{\text{Inflation Coefficient}}{2 * \text{Inflation-Squared Coefficient}} \tag{6}$$

Pollin and Zhu (2006) include eleven variables in their regressions to estimate the growth rate of real per capita gross domestic product (GDP), as measured by the difference between logged values. I discuss each of the independent variables in turn in order to describe the environment in which Pollin and Zhu (2006) and this study examine inflation and to provide expected signs for the coefficients (i.e., positive, negative, or ambiguous). These expectations are determined by the literature.

1. **The share of government consumption in GDP**: High government consumption relative to GDP suggests that the private sector is not particularly robust. This undermines growth by limiting innovation. This can be particularly detrimental to growth in the long-run. During economic crises, though, fiscal stimulus may be effective in stabilizing and rebalancing the economy, thereby leading to higher growth. While the former observation is fairly universal across economic theories, the latter is particularly Keynesian in nature. Neoclassical economics suggests that fiscal stimulus is not an effective way to reverse a recession. For example, increased fiscal spending may crowd out investment, which discourages businesses from expanding. Further, even if fiscal stimulus does lead to stronger growth, its effects may only be observable with a time lag. Given these factors, I anticipate the sign of government consumption to be **negative**.

2. **The government budget surplus as a percentage of GDP**: A positive government surplus means that tax revenues exceed government expenditures. As such, the surplus will likely be negative (i.e., the country has a budget deficit) during economic

downturns due to a combination of weaker tax receipts, automatic stabilizers (government programs, such as unemployment insurance, that engage during a recession independently of government action), and potential attempts at fiscal stimulus. If governments run prolonged negative budget surpluses, they generally need to go into debt in order to sustain their spending. Government borrowing can crowd out private borrowing, thereby curbing investment and undermining economic growth. For these reasons, government budget surpluses should have a **positive** impact on growth.

3. **The share of investment in GDP**: High shares of investment in GDP lead to higher stocks of capital in the economy, which enhance labor productivity, promoting growth. Additionally, investment can lead to technological innovation, which also spurs growth. As such, higher levels of investment should have a **positive** impact on growth.

4. **Initial level of per capita GDP**: This is an indicator of a country's level of economic development at the beginning of the period. Convergence theory suggests that, upon achieving the steady state, all countries will be at the same level of per capita output. If this is true, high levels of per capita GDP will have a negative impact on growth, particularly in the long run. The evidence for such an effect has been mixed: some studies (e.g., Lucas, 1988) do not support convergence theory, though Mankiw, Romer, and Weil (1992) do find support for conditional convergence. Additionally, Barro (1996) uses a similar approach to that of Pollin and Zhu (2006) and finds the coefficient of initial per capita output to be negative. As such, the estimated coefficients for this variable are likely to be **negative**.

5. **Life expectancy at birth**: Long life expectancy suggests that individuals in the country have a high quality of life and, in particular, that they are healthy. This should lead to a more productive labor force and, therefore, to stronger growth.

Additionally, high life expectancy provides more opportunities to acquire human capital, and therefore may also enhance labor productivity through this channel as well. Therefore, life expectancy should be **positively** correlated with growth.

6. **Average years of secondary schooling in the adult population**: This is a proxy for the level of human capital in the labor force. A more educated labor force should be able to use more advanced technologies and is predisposed towards innovation. This should be particularly true over long periods of time. As such, education should be **positively** correlated with growth.

7. **Change of terms of trade weighted by the sum of imports and exports as a percentage of GDP**: There are two components to this variable. First, if the variable is positive in sign, it means that the country's terms of trade improved, either because exporters were able to profit more from their sales, consumers were able to import more cheaply, or some combination of the two. Because of this, the trade variable should be **positively** associated with growth. The second component of the variable is the exposure of the economy to foreign markets. Large values of this variable, positive or negative, indicate that trade represents a significant portion of the country's economy. The share of trade in the economy has no influence on the sign of the variable, because trade cannot be negative. However, this factor is important, because it will weight changes in terms of trade by their relevance to national output as a whole.

8. **Share of population affected by natural disasters weighted by the share of agricultural output in GDP**: Natural disasters can both ruin agricultural crops and destroy infrastructure, both of which restrict output. This destruction may take a considerable time to repair, meaning that natural disasters may have prolonged impacts on growth. Natural disasters are therefore likely to have a **negative** impact

on growth.

9. **Participation in armed conflict with more than 25 deaths**: Wars can exact horrific costs on an economy, both through the loss of lives and through the destruction of private property and public infrastructure. Additionally, firms are less likely to invest in war zones, as there are outsized risks that projects will be eradicated and consumer demand is unlikely to be strong. Pollin and Zhu (2006) assign three values to this variable: 1 if a war was recorded within the country's boundaries, -1 if the country participated in a war in another country, and 0 for all instances without war. This specification assumes that participation in foreign wars will have an equal and opposite effect of participation in domestic wars. As I believe that all wars will have negative impacts on growth, I find it difficult to speculate on an expected sign within this framework. Therefore, I regard the coefficient of this variable, given its specification, to be **ambiguous** in sign.

10. **Inflation**: Inflation shall be measured through the consumer price index. As I assume the threshold rate of inflation is non-negative (i.e., either zero or positive), I expect inflation to have the opposite sign of the squared inflation variable. As the model has multiple inputs, the standard second derivative test cannot be used to estimate the sign of the expected coefficient of inflation. For this reason, I classify it as **ambiguous**.

11. **Squared Inflation**: The preceding logic regarding inflation is equally relevant to squared inflation. As such, I expect squared inflation to have the opposite sign as inflation, in order for the threshold rate to be non-negative, but cannot make any inferences on what the sign would be. Therefore, the expected coefficient for squared inflation is **ambiguous**.

In addition to the variables listed above, time dummy variables are included in all of the regressions, to control for any potential omitted variable bias consistent across countries. It is not useful to speculate as to what sign these variables might have, as their importance lies not in their explanatory power, but in their ability to help better estimate the coefficients of the other variables. These dummy variables are only able to inform on what occurred in the past; what the coefficient for the 1970 dummy variable was provides little insight in what may occur in the future.

The countries used in this analysis are listed in Appendix A. The sources used for and constructions of each variable are provided in Appendix B.

3.4 Model Validity

There are two major forms of model validity: internal and external. If the model is internally valid, it is a reliable representation of reality. If the model is externally valid, then the results found here are relevant to populations and periods not included in the sample. I will discuss concerns of validity extensively, as I believe such issues are not sufficiently discussed in the literature.

There are five major biases that may undermine the model's internal validity: omitted variable bias, misspecification of functional form, errors-in-variables bias, missing data and/or sample selection bias, and simultaneous casualty bias (Stock and Watson, 2011).

- Omitted variable bias is a predominant concern, as it skews the estimated coefficients and undermines attempts to make inferences. This study critically examines the approach taken by Pollin and Zhu (2006) to try to minimize the risk of omitted variable bias. A more detailed description of the alterations made is reserved for Section 4.3. Even with these model adjustments, there are certain potential causes of omitted variable bias that are difficult to quantify. For example, Keynesian economics would assert that uncertainty regarding the future impacts growth, principally through investment. However, uncertainty cannot be easily measured and the data that do exist are not broadly available across countries or time. The time dummy variables and FE regressions may reduce this bias to a certain extent, if omitted variables are constant over either countries or time, but this study makes no claim that the risk of omitted variable bias has been wholly mitigated.

- Regarding functional form, Zarnowitz (1985) notes that many of the detriments of growth have nonlinear impacts. Despite this, the vast majority of the independent variables used here are represented linearly. The decision to rely predominately on linear relationships is based on several reasons. First, it is beyond the scope of this study to presume how the relationship between each variable and growth may be nonlinear–does it follow a quadratic curve, a logarithmic progression, or some other path? To determine and test alternative structures for each control variable would be a very time consuming task and would take away from the focus on inflation. Additionally, nonlinearities are most likely to prevalent at the extremes. This assumption was already present in this study, as inflation rates beyond 40 percent are excluded. Between extreme values, I assume that a linear relationship exists between the independent variables and growth. In keeping with Pollin and Zhu (2006), as well as countless other studies, I assume that the linear specification of the majority of variables is appropriate.

  In a few instances, an additional concern regarding functional form is whether the variables chosen for this model are accurate representations of the phenomena they are supposed to depict. For example, the educational variable may not be an effective proxy of human capital. The specification here relies on the average years of secondary school education in the adult population. Particularly in developed countries, this may not be a reasonable approximation of human capital; the average years of tertiary school education may be more valid. Levine and Renelt (1992) note as well that the use of schooling variables to approximate the stock of human capital may be ineffective, because such data do not account for relative variation in the quality of education. As such, two observations may have the same average years of schooling, but have different levels of knowledge. The data here are unable to account for this.

Concerns of functional form bias may be legitimate. However, limitations in the availability of data prevent these issues from being completely addressed. Even so, it is reasonable to assume that the majority of the control variables used in this study have a linear relationship with growth over moderate values. Ultimately, the potential presence of functional form biases leads me to qualify the inferences made from the regression results.

- Errors-in-variables bias is another major concern for this study. The data used in this study are estimates; estimates which are prone to revision over time. In order to determine whether revisions in the data may be substantial enough to bias the results, I examine differences in the values of the dependent variable used in the regressions here from the values used in Pollin's and Zhu's. As can be seen in Figure 1, countries with higher levels of income tend to have smaller revisions. Lower income countries have large revisions at times. In fact, as shown in Table 1, there are nine instances where revisions were quite extensive and all of these occurred to "low income" countries. Clearly, these revisions are not negligible; in 2002, economists thought Haiti grew by 21.5 percent in 1994. Now the economy is estimated to have contracted by -9.4 percent. More importantly, these revisions are also nonrandom; for example, revisions in high-income countries tend to be smaller in absolute value than those in lower-income ones. This indicates that the error present here is not classical measurement error, which means that coefficient estimates are not necessarily biased toward zero.

Figure 1: Comparison of Data from Penn World Table Versions 6.1 (2002) and 7.1 (2012)

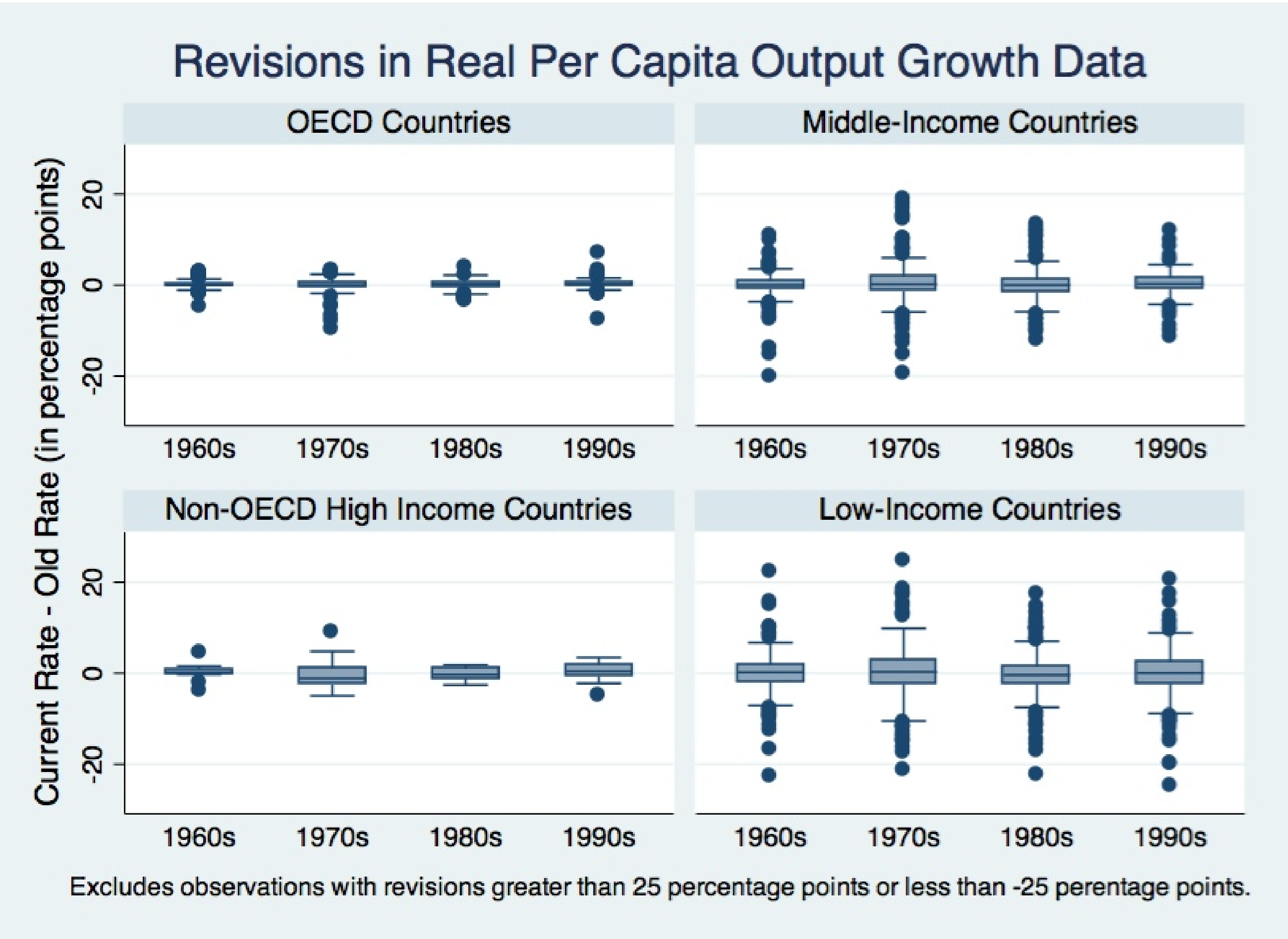

Table 1: Cases Where Revisions in Growth Exceeded ± 25 Percentage Points

Country	Year	Old Growth Rate	Current Growth Rate	Difference
Haiti	1994	21.5	-9.4	-30.9
Haiti	1995	43.0	10.9	-32.1
Mali	1986	-10.1	16.0	26.1
Nicaragua	1980	-6.9	29.3	36.2
Rwanda	1995	30.1	83.7	53.6
Sierra Leone	1996	3.7	-24.8	-28.5
Togo	1980	23.4	-7.4	-30.8
Togo	1994	-17.8	12.6	30.4
Uganda	1981	42.5	-1.5	-44.0

All values measured in percentage points.

Old growth rate data from Penn World Table version 6.1, current data from version 7.1.

It is beyond the scope of this paper to look more closely at these revisions. To be clear, there is no a priori reason to believe that the revisions in output growth correlate with revisions in other variables; the extent to which this is the case will be intimated by the comparison between Pollin's and Zhu's findings and the updated ones here. I make two key assumptions regarding the data. I assume that the revisions brought the data more closely in line with their true values. Additionally, I infer from their large prior revisions that the data are less reliable for middle- and low-income countries. For this reason, I will make few conclusions from the regressions on these data. To summarize, there is substantial evidence to suspect the quality of the data. However, aside from limiting inferences from the least reliable countries, there are few ways in which this risk can be mitigated.

- Missing data and sample selection bias are also of concern to this study. The dataset is not complete; there are numerous observations that do not have data for at least one variable. It is unlikely that such missing observations are randomly distributed across countries and time. Attempts were made to include as much data as possible, while keeping the information used as current as possible. In particular, additional sources were used to obtain data for terms of trade and for government budget surpluses, as detailed in Appendix B. Ultimately, however, there were few alternative datasets that could be used to fill in the missing data.

Regarding sample selection bias, the countries included in this study are quite diverse. However, there are three major sets of countries that appear to be systematically excluded from the dataset: former Soviet states and relatively new European states (e.g., a united Germany), oil-producing states, and relatively economically isolated countries (Cuba and North Korea, in particular). The unique phenomena associated with these countries provide a rationale for their exclusion from the dataset. As such, sample selection bias is not a major concern for this study.

- Lastly, simultaneous causality bias is of significant concern. It is a tacit assumption of the regression models that the input variables are exogenously determined. I have, in fact, consistently referred to them as independent variables. While convenient, this assumption is not particularly reasonable a priori. For example, businesses likely rely on recent years' economic growth to gauge future activity. As such, economic growth in the past likely impacts investment decisions in the present.

  Additionally, inflation, too, may be endogenous with respect to growth. During a recession, policymakers may seek to use monetary stimulus to promote economic recovery. As such, the growth rate of the economy may influence the rate of inflation. In empirical studies, this concern is largely side-stepped. In Pollin and Zhu (2006), for example, discussion is relegated to a single footnote: they "do not explore the issue of simultaneity or reverse causality in this exercise, although [they] recognize it as an important issue for further research" (Pollin and Zhu, 2006: 603). It is difficult to properly test for simultaneous causality. In particular, the limited time periods available for examination prevent the use of most conventional analyses on causality. While an instrumented variables regression would be able to account for some of the endogeneity, the approach is not readily applicable to this case. It is necessary to have at least as many instruments as there are endogenous variables. Both inflation and squared inflation would be endogenous to growth; finding a second instrument is not inherently straightforward. Presumably, this is why Pollin and Zhu (2006) chose to leave this question for future studies.

It is also possible that simultaneous causality is most prevalent across the short-term. Over longer periods of time, the variables may be exogenous with respect to one another. To the best of my knowledge, this assertion has not been explicitly tested for the variables used here, though there is some theoretical appeal to it. For example, while output-induced factors, such as "demand pull" and "cost push," may impact the rate of inflation, such influences are thought to be negligible beyond the short-term McConnell, Brue, and Flynn (2012). Ultimately, limited availability of data prevents a more rigorous examination of the risk of simultaneous causality, so, following Pollin and Zhu (2006), this potential bias is not tested here. However, based on my belief that such bias is most likely in the short-term, I do not rely on the results from the decade regressions to determine my overall conclusions. As these regressions still provide an opportunity to compare the work done here with that of Pollin and Zhu (2006), they are still of use.

Regarding the external validity of the data, there are two main questions: are the conclusions relevant to countries not included in the dataset and will these conclusions reflect reality in the future? It is very likely that the findings presented here are consistent with the experiences of many of the countries not included in the model. Modern Germany, for example, would likely behave in a similar manner to the OECD countries included here. This study is unlikely, however to be effective in describing the growth of "non-business-oriented" economies. Command economies, oil states, and agrarian societies have unique structures that are beyond the focus here.

Additionally, recall that all observations with rates of inflation beyond 40 percent are excluded from this analysis. As such, the inferences made from this analysis are constrained from properly examining economies during periods of hyperinflation. Burdekin et al. (2004), among others, suggest that the relationship between inflation and growth differs above this threshold. As such, while the exclusion of these observations from this analysis restricts the potential scope of the conclusions, it also reduces the risk of skewing the estimates by excluding outlier observations. For this reason, the benefits of this choice likely outweigh the costs.

The consistency of my findings across time is perhaps the most pertinent question. In particular, is there a structural break in the relationship between one of the independent variables and growth? This model assumes that the true relationships between the independent variables and growth are constant over the period examined. This is an assumption made out of necessity rather than statistical evidence. With regard to inflation in particular, this belief is undermined by countries that have adopted inflation targeting for their monetary policy. This monetarist approach stabilizes inflation about a particular value, such that the rate of inflation is supposed to hold steady even as the economy moves through the business cycle. To the extent that central banks are able to achieve their targets, inflation should be unable to describe the variation in growth, even though it may have been able to do so in the past. If this phenomenon is present in the dataset used here, the current models will be undermined by not accounting for this. If a broader time period was available, there are several time series analyses that could be used to test for the presence of a structural break. However, the limited availability of data undermines my ability to properly address this concern.

To summarize this section, there are numerous sources of potential bias that may impact the regression model used here. Some of these, such as omitted variable bias, can be addressed, at least in part. However, there are others, such as simultaneous casualty and structural breaks, that are impossible to control for at this time. Unfortunately, the only recourse for a proper discussion of these sources of error is to wait for more data to become available. With a sufficiently long period of time available for analysis, econometric tests can be used to determine if these potential sources of error bias the model. In the meantime, the only way I can counter this error is to qualify my conclusions .

4 Results

Here I present the outcomes of the regression analysis and compare them with the findings of Pollin and Zhu (2006). I start by examining the results of the decade analysis, shift to looking at the medium-term results,[4] and propose an augmented model which can be used to relate the Pollin and Zhu framework with the Mankiw, Romer, and Weil (1992) empirical model. Lastly, this augmented model is examined through the twenty-five year averages used by Mankiw, Romer, and Weil. There are two main goals here: test the validity of the Pollin and Zhu (2006) model and compare this model with that of Mankiw, Romer, and Weil (1992). As these models come from very different theoretical perspectives, this comparison should provide some intriguing insights.

The primary way in which I compare Pollin's and Zhu's published findings with my own

[4] Pollin and Zhu refer to these as long-term results. However, to keep the discussion in this paper clear, five-year averages will be referred to as medium-term.

is through the estimated turning point of inflation. In particular, when I replicate their methods, I should come to the same estimated turning points as they do. It is important to understand that, in contrast with Pollin and Zhu (2006), this paper does not make any claims regarding the usefulness of these turning point estimates for policymakers. In particular, when the estimated coefficients of inflation and inflation-squared are statistically insignificant themselves, the estimated turning point has no explanatory power at all. The turning point estimates are only used as points of reference.

4.1 Decade Results

When I replicate Pollin's and Zhu's decade regressions, I obtain different results from those in the published study. Table 2 displays the Pollin and Zhu (2006) published results, while Tables 3, 4, and 5 present the same regressions using the current dataset.

The results in Table 3 are fairly consistent with the corresponding turning point estimates in Table 2. The estimated turning points have moderate values and do not vary excessively across model specification. However, this is not true for the 1980s or 1990s. Based on my regressions, the estimated turning points in the 1980s were -6.8 percent using OLS and 94.8 percent using FE. These extreme, statistically insignificant values reinforce my reluctance to make inferences based on the turning points. In their regressions, Pollin and Zhu were only able to calculate one estimated turning point for the 1980s, 59.0 percent; for their OLS regression, the zero coefficient estimate for squared inflation implies a linear (though statistically insignificant) relationship between inflation and growth over this decade. My regressions on the 1990s also find inconsistent estimates, with the OLS regression suggesting an inflation turning point at 11.9 percent, while the FE one yields 39.0 percent. There is no overlap between these estimates and the ones found by Pollin and Zhu, which are 4.2 percent and -65.0 percent, respectively. My regressions on the 2000s are more in line

Table 2: Duplication of Table 3 from Pollin and Zhu (2006): All Countries, by Decade

	1961-1970 OLS	1961-1970 FE	1971-1980 OLS	1971-1980 FE
Number of observations	480	480	620	620
Inflation Rate	0.112†	0.065	0.084	0.06
	(1.04)	(0.070)	(0.99)	(0.61)
Squared Inflation	-0.0005†	-0.007**	-.0005**	-0.006**
	(1.47)	(2.10)	(2.00)	(2.21)
Estimated Turning Point	11.2†	4.6	8.4	5.0

	1981-1990 OLS	1981-1990 FE	1991-2000 OLS	1991-2000 FE
Number of observations	718	718	698	698
Inflation Rate	-0.016	-0.118**	0.025	-0.13
	(0.31)	(1.98)	(0.31)	(1.69)
Squared Inflation	0.00	0.001	-0.003	-0.001
	(0.008)	(0.61)	(1.30)	(0.43)
Estimated Turning Point	N/A°	59.0	4.2	-65.0

T-statistics shown in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

† Displayed as published, though the values are inconsistent with one another.

○ Incalculable due to zero in the denominator.

Annual data used.

Control variables not shown.

Table 3: Replication of Pollin's and Zhu's Decade Analysis: 1961-1970 and 1971-1980

	1961-1970 OLS	1961-1970 FE	1971-1980 OLS	1971-1980 FE
Inflation Rate	0.156	0.098	0.025	0.100
	(0.192)	(0.264)	(0.099)	(0.094)
Squared Inflation	-0.010	-0.013	-0.002	-0.005**
Rate	(0.009)	(0.013)	(0.002)	(0.002)
Share of Government	0.092	-0.500	-0.052	0.676***
Spending in GDP	(0.089)	(0.610)	(0.076)	(0.191)
Share of Investment	0.101**	0.120	0.043	0.434***
in GDP	(0.048)	(0.126)	(0.049)	(0.076)
Log Value of Initial	0.125		-0.544	
GDP	(0.538)		(0.747)	
Average Life	0.060	0.079	0.126	0.051
Expectancy at Birth	(0.054)	(0.446)	(0.098)	(0.677)
Average Years of	-0.492*	1.830	-0.643**	2.836
Secondary School Education	(0.288)	(1.523)	(0.310)	(2.861)
Participation in	-0.065	-0.403	0.024	-1.012
Armed Conflicts	(0.468)	(0.561)	(0.521)	(0.757)
Terms of Trade	0.043	0.037	-0.013	0.009
Impact	(0.052)	(0.057)	(0.021)	(0.020)
Natural Disaster	0.258	0.344	-0.434***	-0.601***
Impact	(0.319)	(0.335)	(0.085)	(0.079)
Government Budget	0.043	-0.044	0.073	0.150
Surplus as a Percent of GDP	(0.112)	(0.309)	(0.073)	(0.166)
Estimated Turning Point	7.584	3.824	5.100	9.162
R^2	0.156	0.127	0.156	0.238
R^2-adjusted	0.103	0.075	0.118	0.206
Observations	342	342	470	470
F-statistic	3.797	4.196	14.682	21.816

Clustered standard errors in parentheses. *** $p < 0.01$, ** $p< 0.05$, * $p< 0.1$

Annual data used.

Constant and time period dummies not shown.

Table 4: Replication of Pollin's and Zhu's Decade Analysis: 1981-1990 and 1991-2000

	1981-1990 OLS	1981-1990 FE	1991-2000 OLS	1991-2000 FE
Inflation Rate	-0.030	-0.184	0.156**	-0.115
	(0.075)	(0.112)	(0.076)	(0.133)
Squared Inflation	-0.002	0.001	-0.007***	0.001
Rate	(0.002)	(0.003)	(0.002)	(0.004)
Share of Government	-0.065	-0.148	0.038	0.120
Spending in GDP	(0.050)	(0.364)	(0.056)	(0.436)
Share of Investment	0.018	0.132	0.081**	0.335***
in GDP	(0.051)	(0.088)	(0.031)	(0.063)
Log Value of Initial	-0.071		0.435	
GDP	(0.665)		(0.497)	
Average Life	0.090	0.001	0.031	-0.254
Expectancy at Birth	(0.076)	(0.117)	(0.062)	(0.270)
Average Years of	-0.049	0.426	-0.327	5.233***
Secondary School Education	(0.301)	(2.342)	(0.250)	(1.874)
Participation in	0.829	1.274	0.336	-0.039
Armed Conflicts	(0.622)	(0.901)	(0.447)	(0.613)
Terms of Trade	-0.030	-0.034	0.005	0.038
Impact	(0.026)	(0.025)	(0.022)	(0.027)
Natural Disaster	-0.041	-0.049	0.097	-0.018
Impact	(0.137)	(0.099)	(0.137)	(0.116)
Government Budget	0.000***	0.000***	0.195***	0.200*
Surplus as a Percent of GDP	(0.000)	(0.000)	(0.069)	(0.119)
Estimated-Turning-Point	-6.757	94.844	11.858	39.027
R^2	0.111	0.088	0.190	0.173
R^2-adjusted	0.077	0.055	0.152	0.137
Observations	546	546	450	450
F-statistic	1254.647	806260.6	5.032	9.504

Clustered standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Annual data used..

Constant and time period dummies not shown.

Table 5: Replication of Pollin's and Zhu's Decade Analysis: 2001-2010

	2001-2010 OLS	2001-2010 FE
Inflation Rate	0.205*	0.090
	(0.122)	(0.127)
Squared Inflation	-0.009	-0.006
Rate	(0.006)	(0.006)
Share of Government	-0.011	0.048
Spending in GDP	(0.067)	(0.179)
Share of Investment	0.122***	0.214***
in GDP	(0.035)	(0.061)
Log Value of Initial	-0.334	
GDP	(0.335)	
Average Life	0.038	0.242
Expectancy at Birth	(0.032)	(0.317)
Average Years of	-0.339	0.012
Secondary School Education	(0.238)	(1.522)
Participation in	0.494**	0.289
Armed Conflicts	(0.228)	(0.259)
Terms of Trade	0.034**	0.012
Impact	(0.015)	(0.016)
Natural Disaster	-0.040	-0.440***
Impact	(0.206)	(0.087)
Government Budget	0.047	0.182***
Surplus as a Percent of GDP	(0.040)	(0.065)
Estimated Turning Point	11.790	8.171
R^2	0.345	0.409
R^2-adjusted	0.324	0.389
Observations	583	583
F-statistic	11.367	16.314

Clustered standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Annual data used.

Constant and time period dummies not shown.

with those for the 1960s and 1970s, with turning point estimates of 11.8 percent and 8.2 percent. I had the greatest success in obtaining observations for this decade and was able to explain considerably more variance in output growth. While this may suggest that the regressions for this decade are the most robust, again I emphasize that the same cannot be said for the estimated turning points in Table 5; just one of the inflation coefficients for this decade is significant at the 10 percent level.

There are two key findings from these results. First, it appears that I am generally less able to find consistent estimates during the decades when there was the most economic volatility, such as in the 1980s. This severely undermines the value of the regression model; I cannot reliably explain the variance in growth during the periods when such explanations are the most critical. Curiously, though, despite the financial crisis that occurred at the tail end of the 2000s, the estimates for that time period were the most internally consistent of any decade's. It is possible that the crisis occurred too late in the decade for its effects to be wholly picked up here. Regardless, the variations in the findings make it difficult to make definitive conclusions from these decade results.

The second, and perhaps more critical finding, is that I am largely unable to exactly replicate Pollin's and Zhu's published findings. While it is reasonable to assume some slight variation in the estimates as countries update their data, the lack of accord between their results and mine is unsettling. When comparing their reported number of observations with mine, they consistently are able to include more observations. While in some cases, the omission of observations in the regressions here may reflect revisions in either a country's population or inflation data, such that the observation is now excluded from the regressions, this explanation is unable to account for all of the missing observations. As such, I assume that data sources had values for particular observations back when Pollin and Zhu were writing, but no longer provide values for those instances today. The reasons why such data would no longer be provided today are not inherently obvious. One hypothetical explanation is that sources found out that accurately estimating values for particular observations was not possible and chose to provide no value at all rather than an inaccurate one. This would suggest that the initial results might be skewed by spurious relationships. Alternatively, my estimates may be biased by a handful of observations, which are better able to influence the coefficient estimates due to the smaller sample size. While finding the reasons behind these discrepancies would likely have important implications for other studies using the same data sources, I find such an investigation to be beyond the scope of this paper. I compensate for this uncertainty by qualifying my conclusions.

4.2 Medium-Term Results

Table 6 displays the Pollin and Zhu (2006) published results over five-year averages, while Tables 7 and 8 present the same regressions using the current dataset.

The medium-term regressions reflect many of the findings of the short-term analysis. In particular, it is generally difficult to find consistent inflation turning point estimates and the inflation coefficients are all statistically insignificant in the regressions performed here. For example, as shown in Table 7, my turning point estimates for all countries is -5.1 percent using OLS and 41.4 percent using FE. For the same population, Pollin and Zhu found estimates of 18.3 percent and 15.2 percent. The OLS and FE specifications are the most consistent when regressing on the OECD countries, where I estimate inflation turning points of -1.9 and -0.7 percent, respectively. In the published study, the inflation turning point estimates were the lowest for the OECD countries, as well. My findings are also fairly consistent with Pollin's and Zhu's for the low-income countries, where my turning point estimates of 18.9 percent with OLS and 16.3 percent with FE compare with their estimates of 18.0 and 23.3 percent. However, the turning point estimates for middle-income countries

Table 6: Duplication of Table 2 from Pollin and Zhu (2006): 1961-2000

	All Countries OLS	All Countries FE	OECD Countries OLS	OECD Countries FE
Number of observations	356	356	135	135
Inflation Rate	0.11**	0.091	-0.055	0.025
	(2.49)	(1.61)	(-0.66)	(0.23)
Squared Inflation	-0.003***	-0.003**	-.005	-0.007
	(-3.73)	(-2.41)	(-1.43)	(-1.79)
Estimated Turning Point	18.3	15.2	-5.5	1.8

	Middle-Income Countries OLS	Middle-Income Countries FE	Low-Income Countries OLS	Low-Income Countries FE
Number of observations	127	127	86	86
Inflation Rate	-0.06	0.028	0.359	0.559**
	(1.12)	(0.31)	(1.38)	(2.38)
Squared Inflation	-0.002**	-0.001	-0.01	-0.012**
	(-2.45)	(-0.84)	(1.55)	(2.20)
Estimated Turning Point	15.0	14.0	18.0	23.3

T-statistics shown in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Annual data used.

Control variables not shown.

Table 7: Replication of Pollin and Zhu: All and OECD Countries, 1961-2000

	All Countries OLS	All Countries FE	OECD Countries OLS	OECD Countries FE
Inflation Rate	-0.015	-0.072	-0.022	-0.008
	(0.058)	(0.065)	(0.093)	(0.104)
Squared Inflation	-0.001	0.001	-0.006	-0.006
Rate	(0.002)	(0.002)	(0.004)	(0.004)
Share of Government	-0.024	0.030	-0.021	-0.278**
Spending in GDP	(0.023)	(0.062)	(0.060)	(0.100)
Share of Investment	0.051***	0.106***	0.025	0.014
in GDP	(0.017)	(0.031)	(0.021)	(0.024)
Log Value of Real	-1.262***		-1.833***	
GDP in 1961	(0.206)		(0.386)	
Average Life	0.152***	0.080**	-0.153**	-0.533***
Expectancy at Birth	(0.021)	(0.039)	(0.059)	(0.163)
Average Years of	0.217	0.047	-0.104	0.054
Secondary School Education	(0.150)	(0.339)	(0.173)	(0.349)
Participation in	0.202	-0.255	0.780	1.060
Armed Conflicts	(0.345)	(0.428)	(0.473)	(0.656)
Terms of Trade	0.016	0.025	0.052	0.047
Impact	(0.018)	(0.021)	(0.080)	(0.062)
Natural Disaster	-0.205*	-0.093	1.325	1.846
Impact	(0.122)	(0.180)	(1.375)	(1.878)
Government Budget	0.089***	0.139***	0.072*	0.105
Surplus as a Percent of GDP	(0.030)	(0.045)	(0.036)	(0.063)
Estimated Turning Point	-5.066	41.409	-1.931	-0.656
R^2	0.387	0.253	0.675	0.651
R^2-adjusted	0.359	0.221	0.632	0.607
Observations	420	420	154	154
F-statistic	23.344	12.187	177.451	142.589

Clustered standard errors in parentheses. *** p < 0.01, ** p< 0.05, * p< 0.1

Data averaged across five-year periods.

Constant and time period dummies not shown.

Table 8: Replication of Pollin and Zhu: Middle- and Low-Income Countries, 1961-2000

	Middle-Income Countries OLS	Middle-Income Countries FE	Low-Income Countries OLS	Low-Income Countries FE
Inflation Rate	0.016	-0.034	-0.145	-0.118
	(0.090)	(0.095)	(0.127)	(0.134)
Squared Inflation	-0.002	-0.000	0.004	0.004
Rate	(0.002)	(0.003)	(0.004)	(0.004)
Share of Government	-0.074**	-0.054	0.004	0.069
Spending in GDP	(0.036)	(0.137)	(0.023)	(0.129)
Share of Investment	0.021	0.110	0.046	0.102
in GDP	(0.020)	(0.073)	(0.036)	(0.061)
Log Value of Real	-1.640***		-0.996**	
GDP in 1961	(0.434)		(0.370)	
Average Life	0.070	0.112	0.171***	0.169**
Expectancy at Birth	(0.042)	(0.094)	(0.055)	(0.071)
Average Years of	0.405	-0.086	-0.450	1.679
Secondary School Education	(0.346)	(1.068)	(0.733)	(1.086)
Participation in	-0.474	-0.576	1.409	0.119
Armed Conflicts	(0.456)	(0.593)	(0.923)	(0.979)
Terms of Trade	-0.013	-0.016	0.063*	0.043
Impact	(0.029)	(0.034)	(0.034)	(0.049)
Natural Disaster	-0.451	0.644	-0.234	-0.194
Impact	(0.600)	(0.584)	(0.153)	(0.242)
Government Budget	0.090	0.191**	0.115	-0.031
Surplus as a Percent of GDP	(0.059)	(0.078)	(0.080)	(0.112)
Estimated Turning Point	4.134	-58.946	18.930	16.331
R^2	0.370	0.305	0.310	0.217
R^2-adjusted	0.283	0.215	0.168	0.066
Observations	149	149	106	106
F-statistic	32.171	13.227	14.762	36.411

Clustered standard errors in parentheses. *** p < 0.01, ** p< 0.05, * p< 0.1

Data averaged across five-year periods.

Constant and time period dummies not shown.

in Table 8 are highly inconsistent with one another, with one being 4.1 percent and the other being -58.9 percent. Interestingly, Pollin's and Zhu's estimates were quite consistent for this population, with one being 15.0 percent and the other being 14.0 percent.

One possible explanation for this discrepancy is the number of countries examined. For example, while Pollin and Zhu report 356 observations over this time period using all countries, the regressions here use 420. The additional observations appear to be fairly evenly distributed across country type, with 19 coming from OECD countries, 22 coming from middle-income countries, and 20 coming from low-income countries, while the final 3 are from high-income, non-OECD countries (Israel and Singapore). Additionally, as disused in Section 3.4 and made evident in Figure 1, I cannot rule out the possibility that extensive data revisions also contributed to changes in the coefficient estimates. As the original dataset is not available for examination, I am unable to more definitively address this question. Regardless, as in the decade analysis, I cannot replicate Pollin's and Zhu's (2006) findings.

At this point, I depart from comparing my regression results with those of Pollin and Zhu (2006) and shift my attention to the regression model itself. First, I expand the time period examined to include the 2000s. If the regression model is robust, the coefficient estimates should be consistent with the inclusion of this additional decade. Tables 9 and 10 display the results of these regressions. As shown in Table 9, the expansion of the time period led to far more consistent inflation turning point estimates for the overall sample regressions, with the OLS estimate of 4.7 percent and the FE estimate of 2.4 percent being far more plausible than the estimates in Table 7. The OECD turning point estimates are also comparable to one another and are fairly in keeping with the estimates in Table 7. Table 10 shows that the expansion of the time frame led to less consistent turning point estimates for middle- and low-income countries. In particular, middle-income countries' estimates

Table 9: Expansion of Pollin and Zhu: All and OECD Countries, 1961-2010

	All Countries OLS	All Countries FE	OECD Countries OLS	OECD Countries FE
Inflation Rate	0.025	0.009	-0.001	0.025
	(0.050)	(0.055)	(0.089)	(0.123)
Squared Inflation	-0.003*	-0.002	-0.005	-0.007
Rate	(0.002)	(0.002)	(0.003)	(0.004)
Share of Government	-0.013	0.036	-0.004	-0.248**
Spending in GDP	(0.024)	(0.059)	(0.060)	(0.110)
Share of Investment	0.058***	0.081***	0.025	0.018
in GDP	(0.018)	(0.029)	(0.021)	(0.035)
Log Value of Real	-1.154***		-1.542***	
GDP in 1961	(0.187)		(0.262)	
Average Life	0.133***	0.067	-0.154***	-0.348**
Expectancy at Birth	(0.021)	(0.050)	(0.053)	(0.141)
Average Years of	0.076	-0.585**	-0.082	-0.320
Secondary School Education	(0.113)	(0.260)	(0.148)	(0.374)
Participation in	0.452*	0.470	0.611**	0.287
Armed Conflicts	(0.232)	(0.284)	(0.261)	(0.434)
Terms of Trade	0.028	0.029	0.095	0.050
Impact	(0.017)	(0.018)	(0.060)	(0.058)
Natural Disaster	-0.131	-0.222**	1.381	1.485
Impact	(0.106)	(0.109)	(1.216)	(1.721)
Government Budget	0.065**	0.111***	0.088**	0.118
Surplus as a Percent of GDP	(0.025)	(0.038)	(0.036)	(0.069)
Estimated Turning Point	4.739	2.441	-0.136	1.898
R^2	0.344	0.231	0.682	0.657
R^2-adjusted	0.319	0.203	0.645	0.619
Observations	551	551	193	193
F-statistic	19.508	9.427	.	264.935

Clustered standard errors in parentheses. *** p < 0.01, ** p< 0.05, * p< 0.1

Data averaged across five-year periods.

Constant and time period dummies not shown.

Table 10: Expansion of Pollin and Zhu: Middle- and Low-Income Countries, 1961-2010

	Middle-Income Countries OLS	Middle-Income Countries FE	Low-Income Countries OLS	Low-Income Countries FE
Inflation Rate	0.008	-0.042	-0.064	-0.094
	(0.069)	(0.077)	(0.102)	(0.119)
Squared Inflation	-0.002	-0.000	0.002	0.002
Rate	(0.002)	(0.002)	(0.003)	(0.003)
Share of Government	-0.063*	-0.146	-0.000	0.103
Spending in GDP	(0.036)	(0.095)	(0.026)	(0.099)
Share of Investment	0.028	0.078	0.047	0.082
in GDP	(0.021)	(0.052)	(0.033)	(0.049)
Log Value of Real	-1.600***		-0.979***	
GDP in 1961	(0.343)		(0.307)	
Average Life	0.056	0.039	0.149***	0.116**
Expectancy at Birth	(0.041)	(0.068)	(0.046)	(0.052)
Average Years of	0.200	-0.622	-0.582	1.001
Secondary School Education	(0.217)	(0.534)	(0.737)	(0.896)
Participation in	-0.492	-0.388	1.066	-0.257
Armed Conflicts	(0.370)	(0.463)	(0.624)	(0.753)
Terms of Trade	-0.005	-0.006	0.071***	0.039
Impact	(0.028)	(0.031)	(0.024)	(0.033)
Natural Disaster	0.031	0.242	-0.187	-0.156
Impact	(0.562)	(0.539)	(0.130)	(0.167)
Government Budget	0.103**	0.183**	0.003	-0.059
Surplus as a Percent of GDP	(0.050)	(0.067)	(0.046)	(0.061)
Estimated Turning Point	2.393	-70.831	20.535	28.980
R^2	0.380	0.293	0.359	0.273
R^2-adjusted	0.311	0.218	0.255	0.161
Observations	199	199	144	144
F-statistic	26.668	21.546	12.203	34.609

Clustered standard errors in parentheses. *** $p< 0.01$, ** $p< 0.05$, * $p< 0.1$

Data averaged across five-year periods.

Constant and time period dummies not shown.

are now 2.4 percent and -70.8 percent. While one of the squared inflation coefficients for the all countries sample is now statistically significant, this is a negligible improvement over the first set of regressions, as it still does not yield a significant turning point estimate. In general, when comparing the results of Tables 7 and 8 with those of Tables 9 and 10, there does not appear to be particularly clear evidence in support of the robustness of the regression model.

4.3 Enhancing the Model

Given the inconsistencies in the inflation turning point estimates, I speculate on potential sources of omitted variable bias. The FE regressions may be partially accounting for some variable not in the model, contributing to the lack of accord between the OLS and FE results. Following Pollin and Zhu (2006), I infer that the regression model is particularly robust if the results do not vary substantially across the OLS and FE specifications. This would imply that all country-specific factors are already captured by the model. I emphasize, however, that in practice it is unlikely for the two methods to yield exactly the same outcomes. I critically examine the variables used in the Pollin and Zhu (2006) regressions to try to find possible alterations to the variables, which may improve the robustness of the model.

As discussed in Section 3.4, I am largely constrained in my ability to improve the regression model by the limited availability of data. However, the "participation in armed conflicts," or war, variable lends itself to a straightforward adjustment. In particular, it can be split into two separate indicators: one for when a country participates in a war within its own borders and another for when it participates in a foreign war. The construction of the original variable, where the former situation was given the value 1 and the latter was given the value -1, implied that domestic and foreign wars have equal and opposite impacts on growth. Pollin and Zhu (2006) do not justify this specification and I am unable to find an explanation to validate this a priori assumption. The number of observations in the dataset, even when averaged into five-year periods, provide more than enough degrees of freedom to include a new variable into the model. Additionally, even if Pollin's and Zhu's tacit assumption is accurate, this new variable specification will be able to reflect that. Lastly, war may be correlated with both inflation and growth, making it a particularly important instance of variable bias for the purposes of this study. Given the costs associated with war, governments may find it necessary to expand the money base in order to sustain the military effort. As such, the misspecification of the war variable may skew the inflation coefficients.

An additional way in which the Pollin and Zhu (2006) model may be enhanced is through the inclusion of population growth. Population growth is a common variable in empirical models focused on inflation's impacts on growth (e.g., Burdekin et al, 2004; Vaona, 2012). As populations grow, the monetary base may need to expand in order to compensate for the increased need for currency. This may be particularly important for less developed countries, where population growth tends to be larger. Additionally, population growth is likely to be correlated with the growth of the labor force, particularly over the long-term. As discussed above, an increasing labor force requires a larger stock of capital just to maintain the current level of productivity. Another benefit of including population growth to the Pollin and Zhu model is that the regression model now fully embeds the empirical augmented Solow (1956) model developed by Mankiw, Romer, and Weil (1992). While Mankiw, Romer, and Weil focus on much longer intervals of time, 25 years, to approximate convergence on the steady state, their explanatory variables should still aid in describing growth over the medium-term.

Tables 11 and 12 display the regression results for the alteration of the war variables and

Table 11: Enhanced Pollin and Zhu Model: All and OECD Countries, 1961-2010

	All Countries OLS	All Countries FE	OECD Countries OLS	OECD Countries FE
Inflation Rate	0.032	0.013	0.021	0.051
	(0.049)	(0.054)	(0.092)	(0.117)
Squared Inflation	-0.003*	-0.002	-0.006	-0.006
Rate	(0.001)	(0.002)	(0.003)	(0.004)
Share of Government	-0.009	0.040	0.000	-0.216*
Spending in GDP	(0.022)	(0.059)	(0.062)	(0.115)
Share of Investment	0.062***	0.083***	0.016	0.027
in GDP	(0.016)	(0.028)	(0.023)	(0.035)
Log Value of Real	-1.277***		-1.518***	
GDP in 1961	(0.179)		(0.273)	
Average Life	0.120***	0.063	-0.176***	-0.436***
Expectancy at Birth	(0.021)	(0.046)	(0.057)	(0.132)
Average Years of	0.101	-0.527*	-0.059	-0.301
Secondary School Education	(0.108)	(0.269)	(0.164)	(0.356)
Participation in a	0.214	-0.351	-0.360	-1.712**
Domestic Armed Conflict	(0.330)	(0.439)	(0.594)	(0.640)
Participation in a	-1.074***	-1.497***	-1.089***	-1.236**
Foreign Armed Conflict	(0.395)	(0.430)	(0.360)	(0.486)
Terms of Trade	0.022	0.028	0.102	0.053
Impact	(0.018)	(0.018)	(0.060)	(0.051)
Natural Disaster	-0.134	-0.199	1.577	1.896
Impact	(0.103)	(0.129)	(1.184)	(1.283)
Government Budget	0.077***	0.113***	0.092**	0.128*
Surplus as a Percent of GDP	(0.027)	(0.038)	(0.037)	(0.067)
Population Growth	-0.393***	-0.150	-0.077	-0.473*
Rate	(0.147)	(0.287)	(0.209)	(0.256)
Estimated Turning Point	5.941	3.687	1.829	4.209
R^2	0.363	0.246	0.688	0.677
R^2-adjusted	0.337	0.216	0.647	0.637
Observations	551	551	193	193
F-statistic	19.742	10.231	.	.

Clustered standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Data averaged across five-year periods.

Constant and time period dummies not shown.

Table 12: Enhanced Pollin and Zhu Model: Middle- and Low-Income Countries, 1961-2010

	Middle-Income Countries OLS	Middle-Income Countries FE	Low-Income Countries OLS	Low-Income Countries FE
Inflation Rate	0.002	-0.036	-0.070	-0.111
	(0.071)	(0.077)	(0.104)	(0.122)
Squared Inflation	-0.002	-0.001	0.002	0.002
Rate	(0.002)	(0.002)	(0.003)	(0.003)
Share of Government	-0.061	-0.130	-0.007	0.102
Spending in GDP	(0.036)	(0.088)	(0.033)	(0.101)
Share of Investment	0.038	0.093*	0.053	0.083*
in GDP	(0.022)	(0.048)	(0.035)	(0.048)
Log Value of Real	-1.623***		-0.864**	
GDP in 1961	(0.342)		(0.311)	
Average Life	0.032	0.017	0.139***	0.081
Expectancy at Birth	(0.038)	(0.052)	(0.048)	(0.069)
Average Years of	0.225	-0.571	-0.566	1.166
Secondary School Education	(0.249)	(0.533)	(0.780)	(0.962)
Participation in a	-0.814*	-0.612	1.394*	0.252
Domestic Armed Conflict	(0.432)	(0.580)	(0.698)	(0.980)
Participation in a	-0.747	0.327	1.167	2.903**
Foreign Armed Conflict	(1.096)	(1.231)	(1.301)	(1.247)
Terms of Trade	-0.008	-0.011	0.071***	0.037
Impact	(0.030)	(0.032)	(0.023)	(0.034)
Natural Disaster	-0.066	0.152	-0.168	-0.202
Impact	(0.504)	(0.519)	(0.138)	(0.185)
Government Budget	0.130**	0.190***	0.009	-0.057
Surplus as a Percent of GDP	(0.055)	(0.063)	(0.048)	(0.061)
Population Growth	-0.693***	-0.992***	0.104	0.322
Rate	(0.233)	(0.357)	(0.252)	(0.287)
Estimated Turning Point	0.651	-28.720	22.012	24.137
R^2	0.408	0.312	0.368	0.291
R^2-adjusted	0.334	0.230	0.253	0.169
Observations	199	199	144	144
F-statistic	24.138	20.698	42.319	139.053

Clustered standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Data averaged across five-year periods.

Constant and time period dummies not shown.

the inclusion of population growth in the Pollin and Zhu (2006) model. The estimated coefficients of the domestic and foreign war variables do not support the tacit assumption made by Pollin and Zhu (2006) that these two types of war have equal and opposite effects on growth. That said, they also undermine my assumption that both domestic and foreign conflicts would be detrimental to growth. In particular, for the low-income country regressions in Table 12, all of the coefficients have positive signs and two of these are statistically significant at ten percent. Regarding population growth, in four out of eight cases, the estimated coefficient is statistically significant at ten percent and has a negative sign in six cases. The negative signs on these coefficients support the findings of Mankiw, Romer, and Weil (1992). There is increased dispersion in the estimated inflation turning points for the all countries and OECD samples, while the estimated turning points for the low-income countries become more consistent with one another. The most dramatic impact of the inclusion of population growth can be seen in the middle-income countries, shown in Table 12. In particular, the estimated turning point in the FE model had been approximately -70 percent in the previous specification and has now fallen to a less implausible -28.7 percent. While the estimated coefficients for inflation and squared inflation are still highly insignificant, the inclusion of population growth to the model still appears to have improved its reliability.

While there is some evidence to suggest that the Pollin and Zhu model has been improved by the alterations made here, I am still unable to find a model that has statistically significant coefficients for both inflation and squared inflation. Joint hypothesis tests on the inflation and squared inflation coefficients will also be able to determine if there is a statistically significant relationship between inflation and growth. Joint hypothesis tests have more explanatory power than independent confidence tests, because they can account for joint variation between variables. As such, while the regressions above do not indicate that the relationship between inflation and growth is quadratic in nature, they may still be able to indicate the presence of a significant effect.

An examination of joint hypothesis tests is appropriate here due to the distribution of inflation over the five-year averages. If inflation rates were widely distributed (i.e., with some being highly negative and others being highly positive), there would be little correlation between inflation and squared inflation. However, two factors contribute to the variables being highly correlated. First, just four observations had negative inflation rates over five-year averages, with the lowest being -3.0 percent. As such, the vast majority of the 551 observations used in the medium-term analysis had positive rates of inflation and squared inflation. Second, a significant portion of the inflation rates had low, positive values; the median inflation rate was 6.6 percent. The exclusion from the sample of all observations with inflation rates greater than 40 percent contributes to this low median rate. The implication of the low, positive values of many inflation rates is that the squared rates of inflation are also relatively low. Together, these factors demonstrate the high correlation between inflation and squared inflation.

As shown in Table 13, when using 10 percent as the critical value, the joint hypothesis test conclusions do not differ based on the model examined. With the all countries and OECD samples, the null hypothesis that the true coefficients of both inflation and squared inflation are zero is consistently rejected. By contrast, for the middle- and low-income country samples, the null hypothesis is not rejected even once.

The findings of Table 13 imply that a significant ceteris paribus relationship between inflation and growth does exist for OECD countries in the medium-term. Regarding middle- and low-income countries, I am hesitant to emphatically conclude that such a relationship does not exist for these countries. As I have described in more detail above, I find the quality of the data for these countries to be suspect. Further, it may be that the inflation-

Table 13: Joint Hypothesis Tests of Inflation and Squared Inflation: 1961-2010

Country Type	Regression Type	Original Model	Altered War Variable	Population Growth Included
All Countries	OLS	10.87***	10.1***	
	FE	2.85*	2.94*	
OECD Countries	OLS	15.64***	7.15***	
	FE	12.79***	5.1**	
Middle-Income Countries	OLS	1.42	1.38	
	FE	0.42	0.76	
Low Income Countries	OLS	0.65	0.24	
	FE	0.41	0.78	

H_0: The true coefficients of inflation and squared inflation are both zero.

F statistic values shown. *** $p < 0.01$, ** $p< 0.05$, * $p< 0.1$

growth relationship does exist, but cannot be well approximated by a linear or quadratic trajectory. Further research would be required to determine if output growth in middle- and low-income countries is independent of the inflation rate over the medium-term. What can be said here is that the approach taken by this study is unable to find a significant relationship.

My last examination of this augmented model over the medium-term focuses on the signs of the explanatory variables' estimated coefficients (displayed in Tables 13 and 14). Given the confidence I have in my priors, the estimated coefficients here should reflect these initial assumptions (discussed in Section 3.3). Instances where this is not the case may indicate that the variable in question was weakly specified. When discussing statistical significance here, the critical value will be at 10 percent, unless otherwise specified.

- For inflation, my initial assumption that inflation and squared inflation variables would have coefficients with opposite signs is supported in seven out of eight cases.

However, the OLS squared inflation coefficient for the all countries sample is the only inflation coefficient to be statistically significant.

- For government spending as a share of GDP, my hypothesis of a negative coefficient is supported in just five out of eight cases. Only the FE coefficient for OECD countries is statistically significant.

- Seven of the government budget surplus coefficients are positive in sign and six of these are statistically significant. This was one of the more consistent variables in the model.

- Investment spending, too, was a highly consistent variable, with all eight coefficient estimates having the anticipated positive sign. Four of these estimates were statistically significant.

- The initial level of GDP consistently had a negative coefficient and was significant at at least 5 percent in each of the OLS models. As it is constant over time, this variable was excluded from the FE regressions. Part of the strong statistical significance of this variable may be due to its ability to pick up some of the bias controlled for in the FE regressions.

- For average life expectancy, the coefficient had the expected positive sign in six of eight cases. Of these six coefficients, two were statistically significant. However, the coefficient was negative and statistically significant at 1 percent in both the OLS and the FE regressions on the OECD countries.

- The education variables' coefficients only had the anticipated positive sign in three instances. As mentioned above, I have concerns regarding this variable's specification. To summarize, secondary schooling may not be a relevant indicator of human capital in more developed countries and the specification here is unable to account for variations in educational quality. This may help explain why the only statistically significant coefficient for the education variable is negative.

- The war variables generally support the initial assumption of a negative relationship. Five of eight of the coefficient estimates for both domestic and for foreign wars had negative signs. In only two instances did the coefficients reflect the opposite impacts of foreign and domestic wars tacitly implied by the specification made by Pollin and Zhu (2006). Interestingly, all of the war coefficients for low-income countries had a positive sign, and two of these were statistically significant.

- For the terms of trade variable, the prior assumption of a positive coefficient was supported in six out of eight cases, while both of the estimated coefficients for middle-income countries were negative. This variable was only statistically significant once, though it had the anticipated positive sign.

- For the natural disaster variable, the assumption of a negative association with growth was supported in five out of eight cases, though both of the coefficients for OECD countries were positive. None of the estimated coefficients for this variable was statistically significant. It is possible that the additional weighting by the share of agricultural output in GDP undermined this variable's explanatory power for more developed countries. For example, when a 2005 hurricane destroyed much of New Orleans in the United States, the costs to growth from this natural disaster were likely born out through its impact on trade rather than on agriculture.

- Lastly, population growth had a negative impact on output growth is six cases, though both of the estimated coefficients for low-income countries were positive. Four of the eight coefficients were statistically significant, and each of these had the negative sign reflected by the results of Mankiw, Romer, and Weil (1992).

Taken as a whole, the enhanced Pollin and Zhu (2006) model largely confirms with my initial priors. It is impossible to determine here what caused the discrepancy between the initial assumptions and the actual coefficient signs. It is possible these instances may indicate occasions where variable misspecification undermines the approach. Alternatively, countries at various levels of development may be affected differently by these explanatory variables. Lastly, the potential error in the data may be a factor here, as well. I find that this close scrutiny of the regression results helps indicate areas that may benefit from further examination by future studies.

4.4 Examining Growth in the Long-Term

Section 4.3 enhanced the Pollin and Zhu (2006) model and indicated that inflation may have a significant relationship with growth over the medium-term, at least for highly developed countries. As mentioned then, one of the advantages of the enhanced Pollin and Zhu model is that it contains all of the explanatory variables used in Mankiw, Romer, and Weil (1992). As such, I can compare the more Keynesian approach used in Section 4.3 with one of the standards of neoclassical literature. In particular, I can expand the time frame examined to the twenty-five year averages used in Mankiw, Romer, and Weil (1992). For this section, the samples examined will reflect those of Mankiw, Romer, and Weil (1992), which are slightly different from those of Pollin and Zhu (2006). In addition to the all countries sample, the OECD sample and an "intermediate" sample will be used, as well. The intermediate sample includes the middle- and low-income countries used in Pollin and Zhu (2006) and is used to approximate the 75 "intermediate" countries included in Mankiw, Romer, and Weil (1992). The intermediate sample will not be identical to that of Mankiw, Romer, and Weil (1992), due to data availability, but will instead rely on the data used earlier in Section 4. As the the high-income non-OECD countries do not neatly fit into either subsample of Mankiw, Romer, and Weil (1992), they are excluded from the all countries regressions here.

There are several alterations between the regressions run here and the ones run by Mankiw, Romer, and Weil (1992). The first is that I omit two variables used in Mankiw, Romer, and Weil (1992): technological growth and depreciation. In their paper, Mankiw, Romer, and Weil assume that these variables are constant both across countries and over time. As such, while these variables will impact the coefficient estimates, they can have no impact on the statistical significance of the coefficients or the ability of the model to account for the variance in growth. Additionally, while their education variable measures the average share of the adult population enrolled in secondary school, mine averages the years of secondary schooling in the adult population. Lastly, while Mankiw, Romer, and Weil (1992) examine the 26 year period from 1960 to 1985, I choose instead to divide my time period into 25-year increments: 1961-1985 and 1986-2010. I found this to be preferable over ignoring nearly half of the dataset.

There are also several key differences between the methodology here and the one used earlier in Section 4 (and in Pollin and Zhu(2006)). The most critical of these is that the dependent variable is now measured as the difference in logged values of per capita real GDP in the first and last year of the time period. This differs from the annual differences taken earlier in Section 4.1 and averaged over five-ear increments in Sections 4.2 and 4.3. The input variables in Mankiw, Romer, and Weil (1992),with the exception of the initial log value of GDP, are created by averaging annual data, which is consistent with Pollin and Zhu (2006). Additionally, following Mankiw, Romer, and Weil (1992), the log values of investment in GDP, population growth, and averages years of schooling are used in the regressions, while in Pollin and Zhu (2006) variables were used in their non-logged form (with the exception of initial GDP). The initial level of GDP included in the regressions here will be taken from the first year of each period, which differs from the approach taken in Pollin and Zhu (2006) and earlier in Section 4. Again, this is to be consistent with Mankiw, Romer, and Weil (1992). The additional variables in the enhanced Pollin and Zhu (2006) model will be used in their non-logged form, as the logged value is not always available. For example, if a country runs chronic negative budget surpluses, it cannot be included in the regressions, as it is impossible to take the log value of a negative number. I chose to alter the methodology to reflect that of Mankiw, Romer, and Weil (1992), rather than to remain consistent with Pollin and Zhu (2006), so as to provide the most informative test of the additional variables within the Mankiw, Romer, and Weil (1992) framework. Table 15 presents regression results just for the the period between 1961-1985, to more precisely recreate Mankiw, Romer, and Weil (1992), while Table 16 displays the results of these regressions for both time periods. Only OLS regressions are shown in Table 15, as panel regressions are not feasible over one time period.

When comparing the findings of Table 14 with those of Table V in Mankiw, Romer, and Weil (1992), I emphasize again that the coefficients are unlikely to be exactly identical on account of the differences listed above. However, the estimated coefficients here should nonetheless be consistent with the published results. Based on the estimated signs of the coefficients, this appears to be the case. There is, however, some variation in the levels of significance of the coefficients, perhaps reflecting the difference in the education variable and the revisions made to the data. Nonetheless, the commonalities between the results here and in Mankiw, Romer, and Weil (1992) support the use of Mankiw, Romer, and Weil (1992) model as a foundation.

The parameters in Table 15 differ in several ways from those in Table 14. The OLS regressions are largely consistent across both models, with some of the estimates even being identical to three decimal places. The major exception to this is the population

Table 14: Recreation of Mankiw, Romer, and Weil (1992) Regressions for 1961-1985 Only

	All Countries OLS	OECD Countries OLS	Intermediate[1] Countries OLS
Share of Investment	0.307***	0.312	0.255***
in GDP†	(0.064)	(0.207)	(0.070)
Population Growth	-0.208***	-0.057	-0.115
Rate†	(0.055)	(0.047)	(0.204)
Average Years of	0.265***	0.110	0.245***
Secondary School Education†	(0.069)	(0.076)	(0.077)
Log Value of Real	-0.259***	-0.469***	-0.217***
GDP in First Year[2]	(0.067)	(0.060)	(0.067)
R^2	0.505	0.812	0.396
R^2-adjusted	0.467	0.762	0.322
Observations	58	20	38
F-statistic	20.022	27.209	5.422

Clustered standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

1: middle- and low income countries.

† As in Mankiw, Romer, and Weil (1992), the log of these variables is used. 2: I.e., the value in 1961 or 1986.

Data averaged across twenty-five year periods, constant not shown.

Table 15: Recreation of Mankiw, Romer, and Weil (1992) Regressions for 1961-1985 and 1986-2010

	All Countries OLS	All Countries FE	OECD Countries OLS	OECD Countries FE	Intermediate[1] Countries OLS	Intermediate[1] Countries FE
Share of Investment	0.360***	0.392***	0.290*	0.598**	0.325***	0.415***
in GDP†	(0.090)	(0.117)	(0.154)	(0.282)	(0.098)	(0.125)
Population Growth	-0.208***	-0.061	0.017	0.192*	-0.373**	-0.325*
Rate†	(0.050)	(0.136)	(0.039)	(0.109)	(0.145)	(0.191)
Average Years of	0.265***	-0.081	0.111*	0.022	0.240***	-0.197
Secondary School Education†	(0.055)	(0.073)	(0.058)	(0.097)	(0.063)	(0.125)
Log Value of Real	-0.254***	-0.547***	-0.466***	-0.472**	-0.235***	-0.542***
GDP in First Year[2]	(0.054)	(0.098)	(0.055)	(0.197)	(0.062)	(0.154)
R^2	0.412	0.506	0.819	0.817	0.371	0.422
R^2-adjusted	0.387	0.486	0.794	0.791	0.333	0.386
Observations	128	128	41	41	87	87
F-statistic	12.735	19.493	45.697	22.125	5.584	10.892

Clustered standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

1: middle- and low income countries.

† As in Mankiw, Romer, and Weil (1992), the log of these variables is used. 2: I.e., the value in 1961 or 1986.

Data averaged across twenty-five year periods, constant and time period dummies not shown.

growth variable for the OECD sample, which now has a positive coefficient, albeit a highly insignificant one. The FE regressions show less adherence to the findings of Mankiw, Romer, and Weil (1992), though the investment and initial GDP variables consistently have the correct signs and are statistically significant. However, the OECD sample again has a positive and significant coefficient for population growth and the education variable for the all countries and intermediate countries both have a negative coefficient. This suggests that the FE models are less able to reflect the findings of Mankiw, Romer, and Weil (1992), which implies that the OLS models should be given more focus.

Table 16 displays the results when all of the additional enhanced Pollin and Zhu variables are included in the regressions. This leads to further differences between the coefficient estimates here and those found in Mankiw, Romer, and Weil (1992). While the population growth variable has marginally improved, with the OECD FE estimate now having the anticipated negative coefficient, three of the education estimates are now negative in sign, as is one of the investment coefficients. This suggests that the framework here is less consistent with Mankiw, Romer, and Weil (1992). Examining the inflation variables, while this is the first set of regressions beyond the short-term where both the inflation and squared inflation coefficient estimates are statistically significant, many of the parameters are insignificant.

As mentioned earlier in Section 4, the correlation between inflation and squared inflation may undermine inferences made from independent examinations of statistical significance. To account for this, joint hypothesis tests on inflation and squared inflation were run on the long-term enhanced Pollin and Zhu (2006) model, the results of which are displayed in Table 17. There appears to be strong support for a significant impact of inflation on growth in the FE models, but no evidence of such a relationship in the OLS models. This ambiguity suggests that a closer examination is required in order to more reliably address

Table 16: Enhanced Pollin and Zhu Model using 1961-1985 and 1986-2010 Averages

	All Countries OLS	All Countries FE	OECD Countries OLS	OECD Countries FE	Intermediate[1] Countries OLS	Intermediate[1] Countries FE
Inflation Rate	0.000	0.020	0.004	0.064**	-0.004	0.008
	(0.013)	(0.013)	(0.042)	(0.031)	(0.016)	(0.014)
Squared Inflation	-0.000	-0.001**	-0.002	-0.004***	0.000	-0.000
Rate	(0.000)	(0.000)	(0.003)	(0.001)	(0.000)	(0.000)
Share of Government	-0.003	-0.006	0.003	-0.099***	-0.006	-0.009
Spending in GDP	(0.008)	(0.009)	(0.012)	(0.025)	(0.008)	(0.010)
Share of Investment	0.278***	0.263**	0.209	-0.126	0.249***	0.332**
in GDP†	(0.084)	(0.116)	(0.138)	(0.200)	(0.080)	(0.133)
Log Value of Real	-0.363***	-0.550***	-0.517***	-0.728***	-0.339***	-0.627***
GDP in First Year[2]	(0.062)	(0.089)	(0.108)	(0.224)	(0.067)	(0.168)
Average Life	0.029***	0.009	0.012	0.010	0.029***	0.009
Expectancy at Birth	(0.006)	(0.008)	(0.014)	(0.031)	(0.006)	(0.009)
Average Years of	0.101*	-0.110	-0.067	0.028	0.049	-0.346**
Secondary School Education†	(0.059)	(0.104)	(0.105)	(0.097)	(0.070)	(0.170)
Participation in a	0.141	0.136	0.177	-0.691	0.169	0.203
Domestic Armed Conflict	(0.116)	(0.153)	(0.197)	(0.684)	(0.126)	(0.131)
Participation in a	0.227	-0.062	-0.052	-0.141	0.142	-0.147
Foreign Armed Conflict	(0.180)	(0.173)	(0.102)	(0.259)	(0.576)	(0.417)
Terms of Trade	0.011	0.027	-0.056*	-0.051*	0.016	0.026
Impact	(0.015)	(0.017)	(0.028)	(0.025)	(0.015)	(0.019)
Natural Disaster	-0.057	-0.069	0.830	1.389	-0.047	-0.020
Impact	(0.052)	(0.057)	(1.106)	(0.827)	(0.058)	(0.058)
Government Budget	0.000	0.029***	0.014**	0.022**	0.000	0.030*
Surplus as a Percent of GDP	(0.000)	(0.010)	(0.006)	(0.008)	(0.000)	(0.017)
Population Growth	-0.150***	-0.015	0.053	-0.002	-0.269**	-0.255*
Rate†	(0.049)	(0.117)	(0.049)	(0.124)	(0.127)	(0.135)
R^2	0.561	0.673	0.900	0.961	0.539	0.646
R^2-adjusted	0.507	0.633	0.847	0.941	0.449	0.577
Observations	128	128	41	41	87	87
F-statistic	47.132	17.785	48.168	168.531	13.826	12.755

Clustered standard errors in parentheses. *** $p < 0.01$, ** $p< 0.05$, * $p< 0.1$

1: middle- and low income countries.

† As in Mankiw, Romer, and Weil (1992), the log of these variables is used. 2: I.e., the value in 1961 or 1986.

Data averaged across twenty-five year periods, constant and time period dummies not shown.

Table 17: Joint Hypothesis Tests of Inflation and Squared Inflation: 1961-1985 and 1986-2010 Averages

Country Type	OLS	FE
All Countries	0.19	2.69*
	(0.828)	(0.075)
OECD Countries	1.80	6.19***
	(0.190)	(0.0081)
Intermediate Countries[1]	0.19	6.32***
	(0.8303)	(0.0035)

H_0: The true coefficients of inflation and squared inflation are both zero.

F statistic values shown, p values in parentheses. *** p < 0.01, ** p< 0.05, * p< 0.1

1: middle- and low-income countries.

this question.

A related question to ask is whether there is any statistical evidence in support of including the addition enhanced Pollin and Zhu (2006) variables into the Mankiw, Romer, and Weil (1992) model over the long-term. This question is answered through F-tests between the full and reduced models. The reduced model is that Mankiw, Romer, and Weil (1992), while the full model includes the remaining enhanced Pollin and Zhu (2006) variables. While, ideally, this procedure would have also been used on the different medium-term models, there are too few degrees of freedom for this test to produce useful results. In particular, the inclusion of time period dummy variables adds nine constraints in addition to the control variables. There are too few countries within the OCED, medium-, and low-income samples to offset this large number of variables. The F statistics across the medium-term would be driven by the large number of variables present across all models, and would therefore not be of much use in gauging the relative effectiveness of the different specifications. Table 18 displays the results from these tests.

Table 18: Nested Model F Test on the Enhanced Pollin and Zhu (2006) Model

Sample	OLS	FE
All Countries	2.230**	3.356****
OECD Countries	0.631	2.918
Intermediate Countries[1]	1.535	2.680**

H_0: The full model has no more explanatory power than the reduced model.

The reduced model is the Mankiw, Romer, and Weil (1992) empirical model

F statistic values shown. *** p < 0.01, ** p< 0.05, * p< 0.1

1: middle- and low income countries.

The results in Table 18 somewhat reflect the ambiguity present in Table 17. While there is no support of including the additional enhanced Pollin and Zhu (2006) variables into the Mankiw, Romer, and Weil (1992) framework for the OECD sample, the FE specifications for the all and intermediate country samples both support such an inclusion, as does the OLS specification for the all country sample. As in Table 17, there is stronger support for additional variables using FE than using OLS, which may in part reflect the difficulties the FE model had at reflecting the findings of Mankiw, Romer, and Weil (1992).

It is also possible that the large number of variables included here overwhelms the model. While some of the enhanced Pollin and Zhu (2006) variables may increase the explanatory power of the Mankiw, Romer, and Weil (1992) model, the use of so many variables may mask this. Based on their theoretical backing and Bernanke's and Gürkaynak's (2002) use of the Mankiw, Romer, and Weil (1992) empirical model as a foundation for their work, I can be confident that these core variables are of genuine use. From this starting point, the question shifts to which of the additional variables in the enhanced Pollin and Zhu (2006) model improve over this core model. To answer this question, nested model F tests were run on separate full models of the Mankiw, Romer, and Weil (1992) model with one enhanced Pollin and Zhu (2006) variable included. For the war variables, the

Table 19: Nested Model F Test on Individual Enhanced Pollin and Zhu (2006) Variables

	All Countries OLS	All Countries FE	OECD Countries OLS	OECD Countries FE	Intermediate[1] Countries OLS	Intermediate[1] Countries FE
Government Spending	0.136	0.429	0.000	3.721*	0.118	1.059
Life Expectancy	16.742***	6.001**	0.305	3.635*	11.139***	3.098*
Terms of Trade	0.115	2.547	1.906	1.206	0.162	2.385
Disaster Impact	0.474	4.645**	0.216	1.251	0.180	3.510*
Budget Surplus	0.614	12.119***	2.751	5.812**	0.461	7.870*
Inflation	0.986	0.516	3.771*	5.228**	1.614	5.490**
Inflation/Squared Inflation	0.987	3.375*	2.309	3.275*	0.856	4.191**
War[2]	0.664	0.754	0.465	1.465	0.730	0.858

H_0: The full model has no more explanatory power than the reduced model.

The reduced model is that of Mankiw, Romer, and Weil (1992). The full model incorporates the concept listed above.

F statistics shown, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

[1]These are the middle- and low-income countries. [2]Both domestic and foreign war variables are included here.

two are examined in the same model, rather than independently. Additionally, inflation and squared inflation are also included in one model. Lastly, a full model with just the inflation rate is included, in case the nonlinearities between inflation and growth found in the literature are not present over twenty-five year averages. Table 19 presents the results from these tests.[5]

The additional enhanced Pollin and Zhu (2006) variables are largely unable to increase

[5]As these tests represent a primary step, not all of the 48 regressions associated with them are presented, so as to conserve space. Selected results are provided in Appendix C and the remainder of the regression results is available upon request.

the explanatory power of the Mankiw, Romer, and Weil (1992) variables using OLS. The exceptions to this are life expectancy, which was significant in both the all countries and intermediate samples, and the inflation variable in the OECD sample. Interestingly, the combination of inflation and squared inflation did not significantly improve the OECD OLS regression, suggesting that the quadratic relationship specification for inflation is not optimal for OECD countries over twenty-five years; a linear relationship is more effective. The significance of life expectancy may suggest that the education variable used here is not able to fully capture a country's stock of human capital. For example, life expectancy may be better able to reflect workers' accumulated on-the-job experience. For the FE models, there appears to be a variety of additional variables that provide significant improvements. Only the two war variables and the terms of trade variables are unable to benefit a single model.

Before examining the models used in Table 19 in more detail, an additional set of nested model F tests are run on the inclusion of inflation into them. The war variables and the terms of trade one are not examined, given their inability to improve the Mankiw, Romer, and Weil (1992) model. Two full models are tested: one with the inflation rate included and another with both inflation and squared inflation included. These results are shown in Table 20. Of the models that Table 19 showed to be significantly improved over the core Mankiw, Romer, and Weil (1992) one, the inclusion of inflation concepts improved most of them. However, this only occurred with the models using FE. The inclusion of both inflation and squared inflation appears to have improved more of these models than the inclusion of the inflation rate alone, particularly for the all country sample. This provides support for a nonlinear relationship between inflation and growth, particularly in countries with lower incomes.

The regressions that significantly improve over the Mankiw, Romer, and Weil (1992) model

Table 20: Nested Model F Test on the Inclusion of Inflation Concepts

	All Countries OLS	All Countries FE	OECD Countries OLS	OECD Countries FE	Intermediate[1] Countries OLS	Intermediate[1] Countries FE
The reduced model is that of Mankiw, Romer, and Weil (1992) with the listed variable included. The full model incorporates inflation to this.						
Government Spending	1.161	0.400	3.781*	4.810**	1.874	5.476**
Life Expectancy	0.821	2.226	3.351*	3.820*	0.813	7.919***
Disaster Impact	0.922	0.020	3.382*	4.146*	1.478	3.352*
Budget Surplus	0.616	0.57	1.997	1.573	1.165	6.142**
Inflation[2]	0.987	6.193**	0.880	1.235	0.130	2.687
The reduced model is that of Mankiw, Romer, and Weil (1992) with the listed variable included. The full model incorporates inflation and squared inflation to this.						
Government Spending	1.152	3.929**	2.173	4.848**	1.003	4.741**
Life Expectancy	0.490	3.131*	1.970	1.985	0.409	4.821**
Disaster Impact	0.952	3.131*	2.013	2.629	0.798	3.179*
Budget Surplus	0.686	3.076*	1.393	1.699	0.619	3.589**

H_0: The full model has no more explanatory power than the reduced model.

F statistics shown, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

[1]These are the middle- and low-income countries.

[2]For inflation, the squared inflation variable was included in the full model.

(as shown in Table 19) are provided in Appendix C. Also located in Appendix C are these regressions with inflation concepts, when such variables are found to significantly benefit the model (as shown in Table 20). For the regressions run on the all country sample (Table 21), the education variable is again susceptible to having an implausible sign in the FE specification. The control variables consistently have the same signs: life expectancy has a positive association, the nonlinear relationship of inflation and growth is supported, natural disasters appear to undermine growth, and positive budget surpluses are directly correlated with growth. For the OECD sample (Table 22), the positive sign on many of the population growth variables (six of eight) and the negative sign on half of the education variables suggests that the additions to the model significantly impacted the core Mankiw, Romer, and Weil (1992) variables. It is of particular concern that both of these variables have the wrong coefficient in the OLS specification, which should best adhere to the findings of Mankiw, Romer, and Weil (1992). There is some conciliation in both of these estimates being statistically insignificant. As with the all country sample, the control variables generally support my prior assumptions. The possible exception is that the inflation variables do not largely support a nonlinear relationship. Even when inflation and squared inflation are included, the results of this regression indicate that inflation has an increasingly negative impact on growth. This counters the initial assumption of the optimal rate of inflation being at a nonnegative value. For the intermediate country sample (Tables 23 and 24), the largely negative estimated coefficients on the education variable are of concern, particularly as many of these are statistically significant. These all came from the FE specification, which gives additional reason to suspect the ability of this set-up to reflect the findings of Mankiw, Romer, and Weil (1992). However, all of the control variables have plausible signs. When the inflation rate alone is included, it consistently has a negative sign, and when both it and the squared term are used, the signs are opposite one another, supporting the belief that the optimal rate is nonnegative.

Overall, the variables used in Mankiw's, Romer's, and Weil's (1992) regressions appear to possess a substantial portion of the explanatory power of the enhanced Pollin and Zhu model when the data are examined in twenty-five year averages. These four variables are particularly effective when it comes to explaining growth in the most developed countries. This is particularly true of the OECD sample. Here, there was the lowest support for the inclusion of additional variables, either individually or en masse. While the OLS regressions were able to reflect the findings of Mankiw, Romer, and Weil (1992), the FE specification was more inclined to misspecify certain variables. In particular, the population growth and education variables often had signs contradicting those found in Mankiw, Romer, and Weil (1992). As such, it would seem that the best approach for making inferences and comparisons based on the work of Mankiw, Romer, and Weil is to use OLS instead. The usefulness of inflation in such regressions is unclear. While it benefited many of the models with just one additional enhanced Pollin and Zhu (2006) variable, this improvement was at times at the expense of the Mankiw, Romer, and Weil (1992) variables. If a model is to be used for policy prescription, it is generally preferable that it reflect theoretical findings. For this reason, I am reluctant to make specific inferences from the findings here.

5 Discussion

This paper has spent a considerable amount of time examining the Pollin and Zhu (2006) model to try to find improvements. As has been mentioned extensively, this endeavor was constrained by the limited availability of additional data. However, two improvements were proposed: an alteration of the war variable and the inclusion of population growth into the model. The effects of these additions were not substantial; while the estimated turning points of inflation became more plausible, they were still unreliable due to the nearuniversal statistical insignificance of the inflation variables. However, despite this, the joint hypothesis tests indicated that the ceteris paribus relationship between inflation and growth was, in fact, nonzero for both the all countries and OECD country samples. This indicates that the enhanced Pollin and Zhu (2006) model is only somewhat able to characterize this relationship. It is possible that the exclusion of all observations with inflation rates above 40 percent undermined the models' ability to depict the nonlinear relationship found in previous studies. Future studies may find more success in characterizing the inflation-growth relationship as something other than quadratic. For example, some specifications here have indicated that a linear relationship may be more appropriate. This may be particularly true when studies focus on the growth of middle- and low-income countries. Additionally, when a sufficiently large number of observations are collected, it would be useful to test the stability of the relationships between the control and dependent variables. However, such data are unlikely to be available in the foreseeable future.

Additionally, the extensive revisions to the data on the dependent variable suggest that such changes may have been prevalent throughout the dataset, potentially explaining my inability to replicate Pollin's and Zhu's (2006) results. If this is the case, then the validity of Pollin's and Zhu's findings are severely challenged; errors may have been common in their data. At the same time, the dataset used in this study likely has errors, as well. My ability to confirm Mankiw's, Romer's, and Weil's (1992) findings, even with the differences between their methodology and mine, gives me some faith in the accuracy of those particular data, though errors in data may, to a certain extent, cancel each other out over the course of twenty-five years. As such, I cannot assume that the findings from this study will stand the test of time. I think it would be very valuable to run these regressions in five or ten years with updated data to see whether this is, in fact, the case.

A further extension of Pollin and Zhu (2006) could be to determine whether their control variables are optimally constructed. Over the course of this study, I have inferred from the literature and the regression results that some of the variables may not be appropriately specified. The discussions on the war, education, and natural disaster variables all reflect this. The variation in results across levels of income may indicate another weakness in the approach taken by this study: to what extent is it appropriate to assume that the same set of variables are able to account for growth in both developed and developing nations? The theoretical underpinnings and restrained nature of the Mankiw, Romer, and Weil (1992) choice of variables appears to help make their empirical model effective for both types of countries. However, beyond a core set of variables, it may be more appropriate to construct models specific to the different samples of countries. This is reflected in the long-term findings; when individual enhanced Pollin and Zhu (2006) variables were included in the Mankiw, Romer, and Weil (1992) framework, some variables appeared to be more strongly associated with OECD countries, while others appeared to more strongly benefit intermediate countries.

A related concern is raised by Levine and Renelt (1992). In their study, Levine and Renelt examine a broad number of empirical studies on growth and find that the results are highly sensitive to changes in the variables included in the model. With so many variables in the current regression model (a problem I in fact exacerbated through the enhanced Pollin and Zhu (2006) model), this sensitivity may be particularly pronounced in this study. It may be beneficial to take Levine's and Renelt's (1992) approach and apply it to the relationship between inflation and growth. I tried to do this myself, to a certain extent, but was impeded by my inability to find sufficient data. For example, I thought that a country's debt as a share of GDP would be a better control variable than the annual government budget surplus as a share of GDP, but such data are not readily available for earlier decades. This study has assumed that Pollin's and Zhu's (2006) approach was the correct one. However, based on the findings of Levine and Renelt (1992), another set of control variables may indicate different findings. I am unable to demonstrate that the approach taken by Pollin and Zhu (2006) most accurately characterizes the relationship between inflation and growth. While Pollin and Zhu (2006) were not focused on constructing a long-term growth model, the findings from Section 4.4 suggest that such an approach may not be optimal over twenty-five year averages. With the number of variables used in the Pollin and Zhu (2006) model, the methodology of Section 4.4 (running nested model F tests) is not well-suited to providing useful results, due to the limited number of degrees of freedom

The discussions here and in Section 3 point to numerous weaknesses in the approach taken by this study. I suspect that many of these issues would be relevant to other empirical models. The Mankiw, Romer, and Weil (1992) empirical model appears to be more robust than the Pollin and Zhu (2006) model. In particular, I was more successful in replicating the findings of Mankiw, Romer, and Weil (1992) than I was Pollin and Zhu (2006). This does not represent a complete rejection of Keynesian approaches to growth models; however, it appears that more Keynesian policy proposals are not supported by the long-term data here. This study was not well-suited to addressing the impacts of Keynesian policies over the short-term, though. In particular, while chronic budget deficits may not be beneficial to growth, counter-cyclical budget policies–where deficits are temporary–may be. Addressing this question more completely requires additional analysis. In particular, variable selection should likely be a more restrictive process. Of particular interest to this study is whether inflation should be included in growth models or whether it is superfluous. While my results indicate that inflation may be significant over the medium-term, the ambiguity found in the long-term results suggests that further research would be needed to come to a definitive conclusion.

6 Conclusion

The analysis here leads to several findings. First and foremost, data revisions can be extensive over time. The conclusions from highly detailed empirical models may rely too heavily on the data in their current form and, as such, may lead to different results as data are revised over time. This may explain why I was unable to replicate the findings of Pollin and Zhu (2006). For this reason, I am reluctant to come to a definitive conclusion regarding the growth-maximizing rate of inflation. Rather, I tried to enhance the Pollin and Zhu (2006) model to reduce potential sources of omitted variable bias. This was done through the alteration of the war variable and the inclusion of population growth to the model. This led to only marginal improvements in the model. In particular, as demonstrated by the joint hypothesis tests on the true coefficients of inflation and squared inflation, the decision to reject or not reject the null hypothesis was the same for both the initial and enhanced Pollin and Zhu models. This, combined with my inability to obtain two statistically significant inflation coefficients when the data were averaged across five-year intervals, suggests that my attempts to improve on the original Pollin and Zhu model's capacity to characterize the relationship between inflation and output growth were not particularly successful.

Regarding the outcomes of these joint hypothesis tests, I was unable to reject the null that inflation and squared inflation both have coefficients of zero for middle- and low-income countries over the medium-term, but was able to reject the null when examining all countries and OECD countries over this time period. This indicates some support for a significant ceteris paribus relationship between inflation and growth. However, when the Mankiw, Romer, and Weil (1992) framework was used to examine growth over the long-term (twenty-five year averages), the significance of inflation to growth was ambiguous. This may have been in part due to the use of so many control variables. However, when a selective approach was taken to adding variables to the Mankiw, Romer, and Weil (1992) model, the model's ability to reflect the theoretical findings of the 1992 study were compromised. As such, a growth model excluding inflation may be more appropriate over the long-term.

The implications of these findings for policymakers are decidedly constrained. The results suggest that there may be some room for monetary policy to be engaged without undermining growth in the long-term. That said, the potential impact of inflationary policies over the medium-term (defined here as five years) suggests that such actions may not be costless. This appears to be particularly true in OECD countries; the impacts of inflation on growth in less developed countries are more ambiguous. I am reluctant to infer too much more into the results; there is still risk of omitted variable bias, flawed model specification, and errors in the data. Further, as all observations with inflation rates above 40 percent have been omitted from the dataset, I cannot make inferences about the potential costs of inflation beyond this point. Examining such cases may yield different findings regarding inflation's impact on growth, particularly over the long-term.

What can be said with some certainty is that the approach of Mankiw, Romer, and Weil (1992) is still supported–even with the revisions that have occurred in the data. This model is able to account for a substantial portion of the variance in growth. In fact, the enhanced Pollin and Zhu (2006) model is unable to improve on the Mankiw, Romer and Weil model for OECD countries over the long-term. For less developed countries, there does appear to be some support for the belief that variables beyond the augmented Solow model do significantly impact growth, even in the long-term. Due to the various concerns regarding the validity of the approach taken here, further research into this topic is encouraged.

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A Appendix A: List of Countries Included in Dataset

OECD Countries Countries	Middle-Income Countries Countries	High-Income Non-OECD Countries	Low-Income Countries
Australia	Algeria	Israel	Bangladesh
Austria	Argentina	Singapore	Burundi
Belgium	Bolivia		Cameroon
Canada	Brazil		Central African Republic
Denmark	Chile		Congo
Finland	China		Ghana
France	Columbia		Haiti
Greece	Costa Rica		India
Ireland	Dominican Republic		Indonesia
Italy	Ecuador		Kenya
Japan	Egypt		Lesotho
Korea (South)	El Salvador		Malawi
Netherlands	Guatemala		Mali
New Zealand	Honduras		Nepal
Norway	Hungary		Nicaragua
Portugal	Iran		Niger
Spain	Jamaica		Pakistan
Sweden	Jordan		Papua New Guinea
Switzerland	Malaysia		Rwanda
United Kingdom	Mexico		Senegal
United States	Panama		Sierra Leone
	Paraguay		Togo
	Peru		Uganda
	Philippines		Zaire
	Poland		Zimbabwe
	South Africa		
	Sri Lanka		
	Syria		
	Thailand		
	Tunisia		
	Uruguay		
	Venezuela		

B Appendix B: List and Description of Variables Included in Dataset

Variable	Specification	Source
Per Capita Output Growth	Log value of the ratio between the present and previous periods' real GDP per capita (Laspeyres price)	Penn World Table (PWT) (2012), Version 7.1
Inflation	Increase in the consumer price index	World Bank (2012)
Initial Output Level	Log value of real per capita GDP (Laspeyres price) at the first year of each period	PWT (2012), Version 7.1
Investment	Gross investment in GDP (current prices)	PWT (2012), Version 7.1
Government Spending	Government consumption in GDP (current prices)	PWT (2012), Version 7.1
Government Budget Surplus*	Government budget surplus as a percentage of GDP	World Bank (2012) Easterly (2001) Bruno and Easterly (1995) Easterly, Rodriguez, Schmidt-Hebbel (1994) International Monetary Fund (1998)
Life Expectancy	Life expectancy at birth	World Bank (2012)
Education	Years of secondary schooling in adult population Data given in five-year intervals, annual data taken by assuming linear growth between periods.	Barro and Lee (2011), Version 1.2
Terms of trade*	Change of terms of trade from previous period weighted by the present period's trade dependence ratio (sum of imports and exports as a share of GDP).	Terms of trade data: Easterly (2001) and World Bank (2012). Trade dependence data: World Bank (2012)
Natural Disasters	Share of population affected by reported natural disasters weighted by the share of agriculture in GDP	Natural disaster data: Centre for Research on the Epidemiology of Disasters (2012), Version 12.07. Agricultural data: World Bank (2012)
War	Armed conflicts with at least 25 casualties: events inside a country labeled 1, events outside a country's labeled -1, and all other observations labeled 0	UCDP PRIO Armed Conflict Data Set (2012), Version 4
Population Growth	Annual Population Growth	World Bank (2012)

*For government budget surplus and terms of trade data, multiple sources were used in order to provide a sufficient number of observations. Preference was given to the most recent data available. A listing of precisely which data came from which source is available upon request.

C Appendix C: Additional Long-Term Regressions:

Testing the Impact of Particular Enhanced Pollin and Zhu (2006) Variables Over the Long-Term (1961-1985 and 1986-2010)[6]

[6]Only regressions that were significantly different from the reduced model (see Section 4.4) are shown here. The additional results are available upon request.

Table 21: Regressions on All Country Sample

	OLS	FE	FE	FE	FE	FE	FE	FE
Share of Investment	0.270***	0.359**	0.305**	0.291**	0.257*	0.447***	0.400***	0.341**
in GDP†	(0.072)	(0.124)	(0.130)	(0.145)	(0.136)	(0.111)	(0.115)	(0.122)
Population Growth	-0.140**	-0.028	-0.063	-0.040	-0.055	-0.057	-0.078	-0.086
Rate†	(0.045)	(0.123)	(0.133)	(0.129)	(0.132)	(0.113)	(0.118)	(0.143)
Years of Secondary	0.106*	-0.147*	-0.161*	-0.060	-0.083	-0.130*	-0.147*	-0.103
School Education†	(0.058)	(0.083)	(0.082)	(0.070)	(0.066)	(0.077)	(0.074)	(0.069)
Log Value of Real	-0.337***	-0.577***	-0.570***	-0.529***	-0.494***	-0.621***	-0.591***	-0.520***
GDP in First Year[1]	(0.052)	(0.104)	(0.104)	(0.088)	(0.083)	(0.100)	(0.094)	(0.091)
Life Expectancy at	0.029***	0.019*	0.019*					
Birth	(0.006)	(0.010)	(0.011)					
Inflation Rate			0.014		0.024**		0.021*	0.023*
			(0.014)		(0.012)		(0.012)	(0.013)
Squared Inflation			-0.001*		-0.001**		-0.001**	-0.001**
Rate			(0.000)		(0.000)		(0.000)	(0.000)
Natural Disaster				-0.122	-0.115*			
Impact				(0.077)	(0.066)			
Government Budget						0.034**	0.032**	
Surplus as a Share of GDP						(0.013)	(0.013)	
R^2	0.531	0.547	0.588	0.539	0.579	0.583	0.619	0.553
$R^2 - adjusted$	0.507	0.525	0.560	0.516	0.551	0.562	0.594	0.527
Observations	128	128	128	128	128	128	128	128
F-statistic	15.207	12.611	11.393	16.898	17.861	15.514	13.657	15.724

Cluster standard errors in parentheses, *** p < 0.01, ** p< 0.05, * p< 0.1

† As in Mankiw, Romer, and Weil (1992), the log of these variables is used. [1]I.e., the value in 1961 or 1986.

Data averaged across twenty-five year periods, constant and time period dummies not shown.

Table 22: Regressions on OECD Sample

	FE	FE	FE	FE	FE	OLS	FE	FE
Share of Investment	0.231	0.058	-0.149	0.315	0.413	0.253*	0.347	0.264
in GDP†	(0.333)	(0.220)	(0.228)	(0.186)	(0.298)	(0.145)	(0.269)	(0.240)
Population Growth	0.061	0.183	0.104	0.194	0.166*	0.064	0.308**	0.279**
Rate†	(0.118)	(0.131)	(0.135)	(0.116)	(0.094)	(0.040)	(0.132)	(0.132)
Years of Secondary	0.202	-0.018	0.007	0.010	-0.027	-0.014	-0.195	-0.211
School Education†	(0.175)	(0.178)	(0.153)	(0.083)	(0.081)	(0.058)	(0.151)	(0.146)
Log Value of Real	-0.696**	-0.616**	-0.726**	-0.683***	-0.447**	-0.557***	-0.418*	-0.454**
GDP in First Year[1]	(0.216)	(0.211)	(0.198)	(0.164)	(0.184)	(0.062)	(0.202)	(0.195)
Share of Government	-0.074	-0.063**	-0.081**					
Spending in GDP	(0.048)	(0.030)	(0.030)					
Inflation Rate		-0.058**	0.017			-0.044**	-0.065*	-0.018
		(0.022)	(0.034)			(0.012)	(0.031)	(0.048)
Squared Inflation			-0.004**					-0.003
Rate			(0.001)					(0.002)
Life Expectancy at				0.056**				
Birth				(0.020)				
Government Budget					0.034*			
Surplus as a Share of GDP					(0.016)			
R^2	0.855	0.894	0.920	0.855	0.871	0.858	0.867	0.878
$R^2 - adjusted$	0.830	0.872	0.900	0.829	0.848	0.833	0.843	0.852
Observations	41	41	41	41	41	41	41	41
F-statistic	32.291	35.177	80.939	28.868	33.359	60.971	30.654	49.998

Cluster standard errors in parentheses, *** $p < 0.01$, ** $p< 0.05$, * $p< 0.1$

† As in Mankiw, Romer, and Weil (1992), the log of these variables is used. [1]I.e., the value in 1961 or 1986.

Data averaged across twenty-five year periods, constant and time period dummies not shown.

Table 23: Regressions on Intermediate Sample, Part 1

	OLS	FE	FE	FE	FE	FE	FE
Share of Investment	0.258**	0.394**	0.346**	0.328**	0.310**	0.314**	0.282**
in GDP†	(0.076)	(0.128)	(0.135)	(0.129)	(0.153)	(0.151)	(0.138)
Population Growth	-0.249*	-0.295*	-0.402**	-0.404**	-0.270	-0.369**	-0.366**
Rate†	(0.124)	(0.168)	(0.179)	(0.182)	(0.169)	(0.167)	(0.170)
Years of Secondary	0.077	-0.239*	-0.331**	-0.291**	-0.177	-0.242**	-0.196**
School Education†	(0.063)	(0.131)	(0.116)	(0.097)	(0.115)	(0.114)	(0.090)
Log Value of Real	-0.324***	-0.593**	-0.598***	-0.593***	-0.505***	-0.512***	-0.513***
GDP in First Year[1]	(0.062)	(0.177)	(0.158)	(0.155)	(0.132)	(0.125)	(0.123)
Life Expectancy at	0.028***	0.015	0.019*	0.017			
Birth	(0.006)	(0.011)	(0.011)	(0.011)			
Inflation Rate			-0.015**	0.003		-0.011**	0.013
			(0.005)	(0.014)		(0.004)	(0.014)
Squared Inflation				-0.000			-0.001*
Rate				(0.000)			(0.000)
Natural Disaster					-0.111	-0.075	-0.078
Impact					(0.079)	(0.069)	(0.063)
R^2	0.496	0.459	0.541	0.558	0.463	0.501	0.533
$R^2 - adjusted$	0.458	0.418	0.501	0.513	0.423	0.457	0.485
Observations	87	87	87	87	87	87	87
F-statistic	8.160	7.623	7.362	8.271	9.210	11.132	12.209

Cluster standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

† As in Mankiw, Romer, and Weil (1992), the log of these variables is used. [1]I.e., the value in 1961 or 1986.

Data averaged across twenty-five year periods, constant and time period dummies not shown.

Table 24: Regressions on Intermediate Sample, Part 2

	FE	FE	FE	FE	FE
Share of Investment	0.499***	0.463**	0.438**	0.379**	0.350**
in GDP†	(0.132)	(0.144)	(0.135)	(0.138)	(0.130)
Population Growth	-0.240	-0.338**	-0.346**	-0.423**	-0.423**
Rate†	(0.145)	(0.135)	(0.140)	(0.194)	(0.199)
Years of Secondary	-0.330**	-0.398**	-0.359**	-0.268**	-0.224**
School Education†	(0.153)	(0.141)	(0.131)	(0.122)	(0.094)
Log Value of Real	-0.648***	-0.639***	-0.631***	-0.536***	-0.537***
GDP in First Year[1]	(0.159)	(0.136)	(0.136)	(0.136)	(0.133)
Government Budget	0.037**	0.036**	0.033*		
Surplus as a Share of GDP	(0.017)	(0.016)	(0.017)		
Inflation Rate		-0.013**	0.001	-0.013**	0.010
		(0.005)	(0.016)	(0.006)	(0.015)
Squared Inflation			-0.000		-0.001*
Rate			(0.000)		(0.000)
R^2	0.508	0.568	0.578	0.484	0.514
$R^2 - adjusted$	0.471	0.530	0.535	0.446	0.471
Observations	87	87	87	87	87
F-statistic	6.515	7.658	8.666	11.205	13.393

Cluster standard errors in parentheses, *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

† As in Mankiw, Romer, and Weil (1992), the log of these variables is used. [1]I.e., the value in 1961 or 1986.

Data averaged across twenty-five year periods, constant and time period dummies not shown.