# Macroeconomic Uncertainty and Economic Development
## A cross-country Panel Data Analysis

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**Abstract**

We study how macroeconomic uncertainty hinders economy's development and show that one standard deviation increase in macroeconomic uncertainty reduces GDP by about 1.5 percent and productivity by about 3.5 percent. Despite commonly believed in literature, we show R&D (investment) expenditure channel only partially transmits (does not transmit) the impact of uncertainty to production. We show more developed countries face less macroeconomic uncertainty levels but are more sensitive to changes in them.

***Keywords***— Macroeconomic Uncertainty, Economic Development, Productivity, Financial Development, Panel Data

***JEL codes***— O11, O20, G20, I25, J24

# 1 Introduction

Income level disparity and the vast difference in production per capita across countries have been subjects of countless studies. These differences are commonly attributed to physical and human capital intensity variation across different countries. These two important factors indeed have a substantial impact on total production. Nonetheless, they do not explain the entire gap in production per capita. In fact, as raised by Hall and Jones (1999), the productivity level of countries across the globe is also vastly different. They show productivity differences are huge even after controlling for human and physical capital differences. For instance, production per capita in the U.S. was 35 times more than that in Niger in 1988. The differences in both human and physical capital intensities only cumulatively explain a factor of 4.6 of this gap whereas a factor of 7.7 remains unexplained. Hall and Jones (1999) attribute this to differences in aggregate productivity which stem from differences in institutions and government policies[1]. Both Institutions and government policies determine the long-run economic

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[1] They use the term "social infrastructure"

environment in which the producers produce and households supply labor and capital. According to the existing extensive literature- surveyed partly below- uncertainty is an important factor affecting the economic environment, thereby affecting aggregate productivity levels.

In this paper, we investigate the role of aggregate uncertainty in explaining this productivity gap and income gap in the long-run. We show that long-run macroeconomic uncertainty hinders a country's development process. That is, the perceived uncertainty individuals take into account about stability of economy and the magnitude of future shocks with which they may be hit hampers economy's steady state production and hurts the economic development. We define a notion of uncertainty based on the volatility in macroeconomic variables to find an aggregate measure of uncertainty.

We use a cross-country panel dataset from 1960-2014 and compute countries' relative development levels[2] defined as the income per capita of a country relative to that of the US economy. We show that uncertainty has a significant negative effect on relative development. We show this effect does not fade away after introducing investment and R&D expenditures- the two commonly believed channels to transmit uncertainty impact. Next, we construct aggregate productivity using a Cobb-Douglas aggregate production function considering different production elasticities of capital and labor in different countries. We again show the impact of uncertainty on the aggregate productivity gap.

We also investigate the effect of financial development on the effect of uncertainty. We find that well-financially-developed countries are indeed more sensitive to uncertainty. That is, one standard deviation rise in uncertainty will cause a larger drop in productivity in well-financially-developed countries. Nonetheless, better financial development helps a country to hedge the risks it faces, thereby reducing the average magnitude of uncertainty they must deal with. Taking the magnitudes of uncertainty levels into account, well-financially-developed countries on average face less uncertainty costs despite being more sensitive to them. These results are also robust for the group of countries in higher income level relative to those in lower levels.

The impact of uncertainty on economic growth has been previously investigated in the literature. Ramey and Ramey (1995) consider a panel dataset of 92 countries over the course of 24 years and show that countries with less economic growth volatility have higher levels of average growth. They also show this negative effect is mostly due to innovations in volatility, a notion close to our definition of uncertainty. However, they study economic growth whereas we target economic development by looking at relative production levels between different countries which enables us to investigate the existing development gap.
In another study, Mohaddes and Pesaran (2013) investigate the impact of oil income and oil income volatility in oil-rich countries. They specifically study Iran's data and show despite the resource curse view, oil income has a positive impact on Iran's economic growth. Nevertheless, its volatility has a strong negative impact. Their results are consistent with ours in showing uncertainty hinders development.

A fairly developed body of literature discusses "real options" which refers to a plunge of new investment in an economy following an uncertainty shock stemming from partial irreversibility of investments. Firms take into account the possible out-

[2] We construct relative development by dividing GDP per capita of a country to that of the U.S. in the same year, similar to Hall and Jones (1999)

comes of their investments including the undesirable case in which the investment does not pay off. When uncertainty increases, these undesirable cases expand. Thus, the expected cost of the investment project not being successful rises. Since investment decisions cannot be reversed costlessly, and firms can wait until uncertainty resolves, firms decrease their new investments. For instance, Bloom (2009) studies the impact of uncertainty shocks on economic activities. He empirically derives this impact using a SVAR model. He hand-picks 17 periods in which volatility was significantly larger than its average and constructs a dummy variable that is one in these periods and zero otherwise. He then estimates the impulse response of a change in this dummy variable on production. He shows that with a surge in uncertainty, economic activity freezes and reallocation of labor and capital stops, thereby reducing economic growth. As the uncertainty shock vanishes, reallocation restarts and economic activity gradually returns to its pre-shock levels. In contrast, Valletta et al. (2013) show that reversible investments do not necessarily drop in high uncertainty periods like economic recessions. In fact, firms may prefer to consider these investments. They then explain why firms prefer hiring part-time workers more in recessions. Because full-time workers are subject to different set of rules and the decision of hiring a part-time worker is more easily reversible than a full-time one. As both papers study the impact of uncertainty through investment channel, we investigate the relationship between investment and uncertainty and show that macroeconomic uncertainty does not transmit to the economic development through investment channel.

Fajgelbaum et al. (2017) show high uncertainty decreases firms' participation in production, hence lowering information production about economy's fundamentals- that is obtained when firms produce and observe each other productions- resulting in an undesirable feedback mechanism to firms' participation, thereby prolonging low-participation periods and lowering investment. A notion they refer to as "uncertainty trap". Although this paper pinpoints lack of information production as the immediate cause of investment drop, it still finds a negative correlation between uncertainty and investment. In contrast, our results does not show such a correlation between these two variables.

Arellano et al. (2010) consider the risk premium effect of uncertainty. A surge in uncertainty lowers the expected returns and widens the distribution of possible returns. Thus, firms become more risky, resulting in banks asking a higher risk premium when lending. Thus, cost of capital rises and investment and optimal production levels fall. They also imply that uncertainty transmits to the economy through investment, whereas our results show that as a long run issue, we do not observe such a phenomenon.

Aghion et al. (2009) consider the behavior of capital-constrained firms when being hit by the exchange rate shocks. They show that firms are able to almost fully hedge exchange rate risk in financially developed countries. Thus, the shocks have no significant impacts. On the other side, firms are not able to hedge this risk in financially less-developed countries and production falls following a rise in volatility. We study the impact of uncertainty in different financial development quartiles and find that uncertainty is indeed less for financially developed economies. Nonetheless, these economies are more sensitive to one standard deviation increase in uncertainty than financially less-developed economies.

Aghion et al. (2010) consider uncertainty impact on firm's investment portfolio. They assume long-term and short-term investment opportunities are available for a firm. Long-term investments take a longer time to mature, are subject to unexpected liquidity needs, and have less cyclical returns. They show that if firms are not credit-constrained, the share of long-term investment in total investment will be counter-cyclical such that in economic booms, the firms find it optimal to invest in short-term projects due to their higher cyclical returns. Nonetheless, if firms are credit-constrained, the share may turn pro-cyclical. In such a case, firms are subject to a higher risk of liquidity shortage. Thus, they invest less and average growth rate falls. As long-term investment is also subject to liquidity risk, in economic busts- in which the liquidity shortage risk is even stronger- firms become even less willing to invest in long-term projects, resulting in pro-cyclical behavior of the ratio of long-term investment over total investment, thereby increasing volatility of economic growth. This approach enables them to explain lower average growth rates and higher volatility in less-developed financial markets. Our paper introduces total investment as the transmission channel of uncertainty impact and also introduces the composition of investment as the driving force behind economic growth volatility. We find no empirical evidence supporting the former result. The latter result, however, is outside the scope of this paper but is a potential candidate to explain the transmission of uncertainty impact and a fruitful research direction for future studies.

Although numerous studies have considered the impact of uncertainty on the behavior of economic agents, investment , economic growth, etc to the best of our knowledge the impact of uncertainty on relative development has not been studied before. Our approach enables us to empirically study this relationship in a cross-country setting and show that there exists a negative and significant impact of uncertainty on development. Moreover, our results do not support the effectiveness of the investment channel through which uncertainty is believed to affect the economy. Lastly, we draw an important distinction between average uncertainty level an economy faces and economy's responsiveness to a rise in uncertainty. We show for financially-developed economies, the former is lower but the latter is higher than financially less-developed economies.

# 2 Data

Our empirical work is based on WDI[3] data from World Bank. We obtain country level data for different countries from 1960 to 2014. Variables include GDP, GDP per capita, GDP per capita PPP, new investments, savings, inflation, risk premium, stock market value, total value of stocks traded in a year, investment share of production and R&D share of production, among others. All the variables are real in 2005 USD. We also obtain labor force data including total labor force, population and unemployment rate from the same source. Furthermore, we obtain the commonly used financial development measure (total domestic credit to private firms as a fraction of GDP) from the same source. We include countries income groups in 2014 from World Bank. That is, countries with GNI per capita less than 1035, between 1036 and 4085, between 4086 and 12615, and more than 12615 (all numbers in USD) are respectively classified as low-income, lower-middle-income, upper-middle-income, and high-income countries. We drop countries with population less than one million, observations for which GDP per capita is not available, countries whose income group is not available, and observations for which financial development level is more than 300% of GDP (only three outlier observations) from our dataset. We also drop the observations for

[3]World Development Indicators

which relative GDP per capita or relative capital per capita[4] of a country is below 0.01.

In order to study human development indicators, we use Barro-Lee dataset on educational attainment for different countries. Data is reported in five-year intervals and covers the years from 1870 to 2010. Finally, we collect labor income share of total production from PWT 9.1[5] dataset.

## 2.1 Physical Capital

Physical capital is not reported in WDI. Thus, we construct a measure of physical capital using Gordon formula specified below. We consider 20 years of investment data leading to the current year and assume capital was at its steady state before then. We also consider depreciation rate to be 5%.

$$K_t = \sum_{i=0}^{20} \frac{I_{t-i}}{(1-\delta)^i} + \frac{I_{t-20}}{\delta}(1-\delta)^{20}$$

## 2.2 Human Capital

We use Mincer (1974) method to construct a measure of human capital from Barro-Lee dataset. That is, we translate education attainment to human capital using the following relationship,

$$H = e^{\phi(E)}$$

in which $H$ is average human capital of a labor force and $E$ is average schooling years. Note that $\phi(.)$ has the following form,

$$\phi(0) = 0$$

$$\phi'(E) = \{ \begin{array}{cc} \%13.4 & E < 4 \\ \%10.1 & 4 < E < 8 \\ \%6.8 & 8 < E \end{array}$$

which indicates decreasing returns to additional years of schooling. As educational attainment data is reported in five-year intervals, we interpolate our measure of human capital in the years it is not available.

## 2.3 Productivity

Following the method in the seminal work of Hall and Jones (1999), we estimate country-level productivity values by assuming a Cobb-Douglas production function in the following form,

$$Y = K^{\alpha}(AH)^{1-\alpha}$$

and by Substituting per capita parameters into the production function we estimate productivity by

$$A = \frac{y}{h}(\frac{Y}{K})^{\frac{\alpha}{1-\alpha}}$$

[4]These variables capture relative development level of a country to that of the United States. The formal construction method of these two variables is discussed in section 2.5

[5]Penn World Table

An accurate estimation of capital income share of total production, i.e. $\alpha$, is vital to estimate productivity levels. $\alpha$ is usually assumed to be 0.33 and unique across different countries. However, this estimation is a good approximation only if developed countries are targeted. As we consider a cross-country setting in which countries of different development levels are taken into account, we estimate $\alpha$ separately for each country. Penn World Table reports labor income share of total GDP which represents $1-\alpha$ and through which we can estimate the desired $\alpha$ for each country at each year. If labor income share of total production is not available for a country, we consider the average of that parameter across different countries in the same income group. Income groups are taken from World Bank's definition at the year our sample ends, i.e. 2014. The aforementioned steps enable us to accurately estimate productivity levels of different countries in different years.

## 2.4 Uncertainty

We need to construct a measure of long-term macroeconomic uncertainty that is not severely affected by short-term or mid-term shocks in the economy. Our measure reflects institutional features of a country rather than its transient shocks. Accurate measurement of uncertainty is essential in our analysis. Uncertainty is usually measured by volatility. We define a notion of variance that can be used in our non-stationary setting. If a non-stationary variable $X$ is considered, the uncertainty driven from that variable is as follows;

$$un_t^X = \sqrt{\frac{1}{4}\Sigma_{\tau=t-5}^{t-1}(\Delta log X_\tau - \overline{\Delta log X_\tau})^2}$$

Note that, $\Delta log X_\tau$ shows the growth rate. The expected value of growth rate ($\overline{\Delta log X_\tau}$) is taken over the last five years prior to $t$. We do not use the data on $t_0$ to control for endogeneity in our later specifications. Fraction $\frac{1}{4}$ is used to have an unbiased estimation of variance. All put together, this measure estimates volatility of deviations from the long-run growth in the last five years prior to current year. For robustness purposes, we use different macroeconomic variables from which to estimate economy's uncertainty. Namely, GDP per capita, Production per worker, stock market value, and total stocks traded in a year are all used as input parameter $X$ for our uncertainty measure $un_t^X$. We normalize the uncertainty measures so they have zero mean and unit standard deviation, to make comparison possible.

The cross-correlation of our uncertainty measures are reported in table 1. As can be observed, all these different measures of uncertainty are strongly correlated suggesting that they are all driven by a fundamental macroeconomic uncertainty.
Stock market is usually a good "financial thermometer" of an economy. Therefore, we pick the uncertainty computed using total value of stocks traded in a year, i.e. $un^{st}$, as our main uncertainty measure. Other uncertainty measures are used for robustness check in our analysis.

## 2.5 Relative Development

The main question of this paper is whether macroeconomic uncertainty affects economic development. Development is a long-term concept, thus, short term fluctuations in economic growth may be misleading as far as economic development is concerned.

| | $\mathrm{un}^{ypc}$ | $\mathrm{un}^{ypl}$ | $\mathrm{un}^{mc}$ | $\mathrm{un}^{st}$ |
|---|---|---|---|---|
| $\mathrm{un}^{ypc}$ | 1 | | | |
| $\mathrm{un}^{ypl}$ | 0.774*** | 1 | | |
| $\mathrm{un}^{mc}$ | 0.355*** | 0.246*** | 1 | |
| $\mathrm{un}^{st}$ | 0.166*** | 0.185*** | 0.321*** | 1 |

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Table 1: Correlation table of different uncertainty measures
$un^{ypc}$ : Uncertainty measure computed using GDP per capita
$un^{ypl}$ : Uncertainty measure computed using production per worker
$un^{mc}$ : Uncertainty measure computed using market capitalization (stock market value)
$un^{st}$ : Uncertainty measure computed using total value of stocks traded in a year

Additionally, per capita variables are more informative than aggregate ones in presenting development levels. Thus, we construct development indicators of a country using relative development levels. Our approach is similar to that of Hall and Jones (1999). That is, we divide per capita macroeconomic variables of a country to the corresponding macroeconomic variable of the United States in that year. Therefore, development indicators of United States will all become one. By doing so, we find a good measure of relative development levels of different countries in different years. Note that many seminal studies like Parente and Prescott (1994), Barro and Sala-i Martin (1992), and Sala-i Martin (1996) find convergence in economic growth rates. Thus, each economy will eventually converge to a relative development level, where the explanation of differences in income levels is the concern of the literature. The important question to be answered is, therefore, the underlying driving force behind these gaps between countries' production levels.

We expect relative development to be slow-moving and not to exhibit severe fluctuations. For example, relative GDP per capita yields relative levels between 0.01 and 3.14 (table 2) Furthermore, this approach mitigates the potential non-stationarity of our macroeconomic variables for each country.

Summary statistics of our main variables are shown in table 2. Superscript $r$ denotes that the parameter is the relative value of that variable in a given year divided by that of the U.S. in the same year.

# 3 Empirical Analysis

In this section, we empirically analyze the impact of uncertainty on economic development. We first consider uncertainty impact on GDP per capita. We investigate whether presence of investment or R&D channels mitigates this impact. We then study the impact of uncertainty on aggregate productivity. Finally, we consider the impact of uncertainty in different financial and economic development levels.
Development is a long-term notion and it is not severely affected by shorter-term shocks in business cycles. Therefore, we assume that each country' output fluctuates around its balanced growth path (BGP).

| | Observations | mean | median | S.D. | min | max |
|---|---|---|---|---|---|---|
| $y^r$ | 5510 | 0.26 | 0.08 | 0.35 | 0.010 | 3.14 |
| $k^r$ | 1971 | 0.33 | 0.10 | 0.44 | 0.010 | 2.07 |
| $h^r$ | 3721 | 0.67 | 0.67 | 0.17 | 0.318 | 1.06 |
| $A^r$ | 1702 | 0.32 | 0.10 | 0.38 | 0.003 | 1.49 |
| $\alpha$ | 5513 | 0.48 | 0.48 | 0.12 | 0.136 | 0.91 |
| i (% of GDP) | 4288 | 22.92 | 21.85 | 9.43 | -0.916 | 114.86 |
| R&D (% of GDP) | 1237 | 1.01 | 0.67 | 0.95 | 0.005 | 4.48 |
| FD (% of GDP) | 5002 | 41.16 | 27.69 | 38.35 | 0.059 | 281.27 |
| Observations | 5513 | | | | | |

Table 2: Summary statistics of important variables
$y^r$ : Relative GDP per capita (GDP per capita of a country in a given year divided by that of the U.S. in that year)
$k^r$ : Relative capital per capita
$h^r$ : Relative human capital per capita
$A^r$ : Relative productivity
$i$ : Investment share of total GDP
$\alpha$ : Capital gain share of total production (i.e. production elasticity of capital)
$R\&D$ : R&D share of total GDP
$FD$ : Financial development measure (Total domestic credit to private sector divided by GDP)

We tackle endogeneity issue by constructing uncertainty measures from the past data (not including current data). Therefore, reverse causality is not a concern. To shut down potential endogeneity of our estimations, we also use non-overlapping samples, i.e. five-year interval samples and run the same regression. These five-year intervals significantly mitigate the potential- if any- serial correlation between our variables. We find consistent results for overlapping and non-overlapping samples. We also use Arrelano-Bond estimator to further investigate the validity of our results. It resolves serial correlation issue by using deeper lags of dependent variable as IV. It also tackles presence of economy-specific fixed effects by taking a time difference of variables. Thus, its results are robust with respect to these common endogeneity obstacles. We also check robustness of our results using different uncertainty measures in the next section and show that all the results are consistent with each other.

## 3.1 The Impact of Uncertainty on Relative GDP per Capita

We first estimate the impact of uncertainty on relative GDP per capita using the following model:

$$y^r_{i,t} = (\phi \times y^r_{i,t-1}) + \beta \times un_{i,t} + \Gamma \times Z_{i,t} + f_i + e_{i,t} \tag{1}$$

in which $y^r$ is relative GDP per capita[6], $un$ is our selected measure of macroeconomic uncertainty, $Z$ is the vector of control variables, $\Gamma$ is a vector of coefficients, and $f_i$ is the country fixed effect. The lagged dependent variable is only used in

[6]GDP per capita of country $i$ divided by that of the US.

Arrelano-Bond estimator as it is designed for dynamic panel data models. Consistent with Levine and Renelt (1992) suggestions, control variables include relative capital per capita, relative human capital per capita, investment share of GDP, and R&D share of GDP. The results are shown in table 3.

We do not make any specific assumptions on the production function in our specification. It is distinct from the common approach that assumes Cobb-Douglas production function and uses logarithms of macro variables in the regressions so to yield the results consistent with this assumption. Given we target relative values, the regressions are only consistent with the Cobb-Douglas production function if the capital gain share of total production($\alpha$) is the same for both countries. However, table 8 shows $\alpha$ varies with variations in uncertainty- and more generally with variations in the development stage- which undermines this assumption. Therefore, we do not impose any restrictions on production function and consider linear regression model which enables us to estimate the average impact of uncertainty.

The first column estimates the Pooled OLS regression. The second column estimates the panel model with country fixed effects. The third column estimates the Pooled OLS regression for non-overlapping data, that is only one observation in each five-year interval is used. The fourth column estimates Arrelano-Bond model. The next four columns are similar to the first four in their specification, but with more control variables.

Table 3 clearly shows the impact of uncertainty on relative GDP per capita is significant and negative. The coefficients in columns one and three are almost the same (-1.30% and -1.47% respectively) although we have used a much smaller sub-sample in column three- 180 compared to 903- to deal with endogeneity by using non-overlapping data. The second column also shows a significantly negative impact. Its absolute value, however, is smaller than columns one and three (-0.39%) which is not surprising given that macroeconomic uncertainty is a function of economy's infrastructure, rule of law, etc. Thus, it has a slow-moving nature resulting in a non-negligible fraction of its effect being absorbed by country fixed effects. Column four shows Arrelano-Bond model estimation. The impact of uncertainty is again significant and negative with a coefficient of -0.16%.

Several mechanisms have been proposed to explain how uncertainty transmits through the economy. One strand of these mechanisms imply that the channel through which uncertainty impacts the economy is the investment channel. For instance, "real options" literature suggests a plunge of new investment in an economy following an uncertainty shock stemming from partial irreversibility of investments. Bloom (2009) shows uncertainty shocks freeze reallocation of capital and labor, thereby hampering new investment. Although he studies uncertainty shocks, his results are suggestive for macroeconomic uncertainty impacts on production. Additionally, Fajgelbaum et al. (2017) show high uncertainty decreases firms' participation in production and lowers new investments.

Furthermore, "Risk premium" channel also suggests that uncertainty can impact the economy through new investments. According to Arellano et al. (2010), a rise in uncertainty increases the risk premium that market charges for lending to a firm. Therefore, investment becomes more costly and firms invest less in the new equilibrium with higher uncertainty.

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| | $y^r$ | $y^r$ | $y^r$ | $y^r$ | $y^r$ | $y^r$ | $y^r$ | $y^r$ |
| $un^{st}$ | -0.0130*** | -0.00392** | -0.0147* | -0.00162*** | -0.0158*** | -0.00566** | -0.0161 | -0.00285*** |
| | (-3.95) | (-2.32) | (-1.81) | (-2.89) | (-3.40) | (-2.41) | (-1.16) | (-3.26) |
| $L.y^r$ | | | | 0.919*** | | | | 0.921*** |
| | | | | (82.75) | | | | (56.58) |
| $k^r$ | 0.765*** | 0.140*** | 0.738*** | 0.0228*** | 0.819*** | 0.210*** | 0.803*** | 0.000504 |
| | (106.78) | (7.97) | (44.18) | (3.97) | (73.05) | (8.64) | (27.21) | (0.05) |
| $h^r$ | 0.344*** | 0.172*** | 0.389*** | 0.0263*** | 0.396*** | 0.209*** | 0.447*** | 0.0318** |
| | (11.88) | (6.75) | (5.68) | (2.98) | (10.33) | (5.57) | (4.73) | (1.99) |
| i | | | | | -0.000526 | 0.00153*** | -0.000193 | 0.000785*** |
| | | | | | (-0.88) | (4.75) | (-0.12) | (5.95) |
| R&D | | | | | -0.0270*** | 0.0123** | -0.0275** | -0.00266 |
| | | | | | (-5.41) | (2.44) | (-2.08) | (-1.34) |
| Constant | -0.214*** | 0.250*** | -0.240*** | 0.00464 | -0.233*** | 0.172*** | -0.276*** | -0.000406 |
| | (-10.28) | (10.55) | (-4.89) | (0.55) | (-7.09) | (4.99) | (-3.35) | (-0.03) |
| Observations | 903 | 903 | 180 | 845 | 632 | 632 | 110 | 523 |
| Adjusted $R^2$ | 0.966 | 0.046 | 0.961 | | 0.965 | 0.146 | 0.960 | |
| p | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Fixed Effects | | yes | | | | yes | | |
| Non-overlapping | | | yes | | | | yes | |
| Arrelano-Bond | | | | yes | | | | yes |

$z$ statistics in parentheses
$^{*}$ $p < 0.1$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$

Table 3: The impact of uncertainty on relative GDP per capita
$y^r$ : Relative GDP per capita (GDP per capita of a country in a given year divided by that of the U.S. in that year)
$un^{st}$ : Uncertainty measure computed using total value of stocks traded in a year
$L.y^r$ : Lagged value of $y^r$
$k^r$ : Relative capital per capita
$h^r$ : Relative human capital per capita
$i$ : Investment share of total GDP
$R\&D$ : R&D share of total GDP

Another strand in the literature discusses how R&D expenditures may affect- or be affected by- the macroeconomic uncertainty. Bar-Ilan and Strange (1996) discuss that R&D expenditures and investments in projects with long time-to-build may actually increase during uncertain periods. Uncertainty widens the set of possible returns; thereby significantly improves the returns of the best-case scenarios. Nonetheless, the maximum cost is limited to R&D costs. Therefore, a rise in uncertainty improves the expected return of these projects. Since these projects exhibit a long time-to-build, if firms wait until uncertainty resolves it may already be too late to take advantage of the potential returns. Thus, firms increase their investments in this class of projects in uncertain periods. Our analysis, however, does not support this view. In fact table 8 shows that average R&D expenditures are the same in different uncertainty quartiles.

Taking the potential channels proposed to convey the impacts of uncertainty into consideration, we include investment share of production (% of GDP) and R&D share of production (% of GDP) in our specification to study how the uncertainty impact can change alongside these two variables.

The second four columns of table 3 provide the results by including investment share of production (% of GDP) and R&D share of production (% of GDP) as control variables in the models of the first four columns. Results show that the impact of uncertainty does not fade away by introducing investment and R&D in any of the regressions[7]. Coefficients of uncertainty are generally larger in the second four columns- where investment and R&D are included in the regressions- than their counterparts in the first four columns. The introduction of these two variables changes the impact of uncertainty in the pooled OLS regression from -1.3% to -1.58%. Similarly, the same exercise changes the uncertainty coefficient in the panel model with country fixed effects from -0.39% to -0.56%. Additionally, the same exercise in the Pooled OLS regression with non-overlapping data changes the uncertainty coefficient from -1.47% to -1.61%. Lastly, it changes the uncertainty coefficient in Arrelano-Bond estimator from -0.16% to -0.28%.

As shown in table 8 and discussed in the appendix, average investment shares in different uncertainty quartiles are almost the same. We also further checked this uncorrelatedness by running a regression between uncertainty and investment and found the resulting coefficient is insignificant and close to zero. Thus, unlike commonly believed in the literature and consistent with Ramey and Ramey (1995) findings, our results imply that uncertainty impact is not conveyed through investment channel. Furthermore, as discussed in the appendix, R&D is negatively correlated with uncertainty. But there is a general rise in the uncertainty coefficient when investment and R&D are included in the regressions, suggesting that R&D channel partially transmits uncertainty impact but the majority of variation in uncertainty can not be explained by either channels. The results state that the welfare costs of macroeconomic uncertainty are huge. In fact, one standard deviation rise in uncertainty drops relative GDP per capita by about %1.5.

[7]Unless in the seventh column which uses a much smaller sub-sample. Even in that case, the uncertainty coefficient is similar to other columns but is not significant suggesting that data size issue is the driving force behind higher estimated variance.

## 3.2 The Impact of Uncertainty on Relative Productivity

The next question we tackle is the impact of uncertainty on relative productivity (defined as the the difference of a country's measured aggregate productivity with that of US). The econometric model we consider is:

$$A_{i,t}^{r} = (\phi \times A_{i,t-1}^{r}) + \beta \times un_{i,t} + \Gamma \times Z_{i,t} + f_i + e_{i,t} \tag{2}$$

where $A_{i,t}^{r}$ is the relative productivity of country $i$ at time $t$.

We consider a pooled OLS regression using our entire dataset in columns one to three, a panel regression with country fixed effects in column four, and Arrelano-Bond estimator in column five. We only use lagged value of dependent variable in the Arrelano-Bond estimator.

| | (1)<br>$A^r$ | (2)<br>$A^r$ | (3)<br>$A^r$ | (4)<br>$A^r$ | (5)<br>$A^r$ |
|---|---|---|---|---|---|
| $un^{st}$ | -0.185*** | -0.0284*** | -0.0350*** | 0.00301 | -0.00813** |
| | (-11.97) | (-4.09) | (-3.49) | (0.54) | (-2.40) |
| L.$A^r$ | | | | | 0.764*** |
| | | | | | (26.74) |
| $k^r$ | | 0.712*** | 0.672*** | 0.0733 | -0.0665* |
| | | (47.23) | (27.72) | (1.27) | (-1.74) |
| $h^r$ | | 0.259*** | 0.214** | 0.0410 | -0.0564 |
| | | (4.24) | (2.58) | (0.46) | (-0.88) |
| i | | | -0.00424*** | 0.00295*** | 0.00252*** |
| | | | (-3.27) | (3.86) | (4.48) |
| R&D | | | 0.0293*** | 0.000739 | 0.0195** |
| | | | (2.71) | (0.06) | (2.37) |
| Constant | 0.388*** | -0.149*** | -0.0265 | 0.343*** | 0.112** |
| | (29.25) | (-3.41) | (-0.37) | (4.20) | (1.98) |
| Observations | 903 | 903 | 632 | 632 | 515 |
| Adjusted $R^2$ | 0.136 | 0.849 | 0.834 | -0.071 | |
| p | 0 | 0 | 0 | 0.00429 | 0 |
| Fixed Effects | | | | yes | |
| Arrelano-Bond | | | | | yes |

$z$ statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Table 4: The impact of uncertainty on relative productivity
$A^r$ : Relative productivity
$un_{st}$ : Uncertainty measure computed using total value of stocks traded in a year
$L.A^r$ : Lagged value of $A^r$
$k^r$ : Relative capital per capita
$h^r$ : Relative human capital per capita
$i$ : Investment share of total GDP
$R\&D$ : R&D share of total GDP

Column one of table 4 shows the impact of uncertainty on relative productivity without any control variables. Column two is the same regression but controlled for relative physical and human capital. The comparison shows that the coefficient of uncertainty impact becomes smaller- from -18.5% to -2.84%- when control variables are added. The reason is that countries with high- physical and human- capital levels are more likely to be more productive. Besides, table 8 shows that uncertainty is negatively correlated to physical capital and human capital. Therefore, in absence of these control variables the uncertainty impact absorbs the impact of lack of these capital measures and exhibits a larger coefficient.

Column three investigates if uncertainty impact is conveyed through the investment or R&D channels. Consistent with the discussion following table 3, results do not suggest such mechanisms in effect. In fact, uncertainty coefficient increases in absolute value from -2.84% in column two to -3.50% in column three. Column five estimates Arrelano-Bond model and reports a significant and negative impact of uncertainty with coefficient -0.8%.

The results in Table 8 and the discussions in the appendix show that both physical and human capitals are also negatively correlated with uncertainty. This finding may be in contrast with the predictions in Aiyagari (1994) in which individuals save more capital in more uncertain states or alternatively, higher risk results in more capital accumulation. But is in line with Fernandez-Villaverde et al. (2011) prediction in which capital flows outside the country pursuing more profitable investments. The key element that drives these opposite results is whether a country exhibits openness and free flow of capital. Aiyagari (1994) assumes closed economy whereas Fernandez-Villaverde et al. (2011) does not. As all countries permit some degree of free capital flow, higher capital accumulation in Aiyagari (1994) is not inconsistent with our findings.

Note that our productivity estimation is based on the assumption that the underlying production function is Cobb-Douglas. Whereas, in section 3.1, there is no assumption restricting the underlying production function and the results show the average effects. By the way, the results confirm each other and can be considered as a robustness check. Additionally, as productivity is defined as labor productivity, the net effect on productivity is on average larger than that on GDP per capita (compare coefficients of uncertainty in column five of table 3 and column three of table 4).

## 3.3 Financial Development, Income Group, and the Impact of Uncertainty

Whether financial development or income level influence the impact of uncertainty is an important question because it may clarify the channel through which uncertainty affects the economy. It also provides explicit policy suggestions to mitigate these effects. This is the question we investigate in this section.

Financial development improves the extent to which economic agents insure themselves against the risks they face, such that welfare cost of uncertainty should be less when insuring is an option. Aghion et al. (2009) consider an economy that is subject to exchange rate volatility. They show this volatility has a negative impact on productivity growth when the financial system is not well-developed. But, it does not have any sizable impact with a well-developed financial system. Furthermore- as it is the case in Aiyagari (1994)- financial development reduces precautionary savings of economic agents, should a shock hit them, since they then have alternative sources of funding. Therefore, we expect an improvement in financial development level to mitigate the impact of uncertainty.

Our analysis, however, shows that more developed countries are indeed more sensitive to uncertainty. Nonetheless, average uncertainty levels they experience is lower than less-developed countries, thereby lowering the net negative cost of uncertainty.

We study the impact of uncertainty on relative productivity by constructing four quartiles of financial development. We then run a pooled OLS regression similar to equation 2 controlling for relative physical and human capital in each sub-sample. This approach enables us to observe differential impacts of uncertainty in different financial development levels. We construct sub-samples using last- not current- period's financial development quartile. It enables us to shut down the potential endogeneity between financial development and economic development.

The results are shown in figure 1 in which four quartiles of financial development are placed on the x-axis such that first quartile consists of least financially-developed observations. Dots show the coefficient of impact of uncertainty on productivity for their respective sub-samples. Gray area shows %95 confidence interval.

The results report that the financial development indeed worsens the sensitivity of an economy to uncertainty. In fact, the least developed financial systems have the minimum negative impact while well-developed systems exhibit a significant and large negative impact about -5%. This result may seem contradictory to the literature at first glance whereas it considers another dimension of uncertainty impact. Our results show the response of an economy to one standard deviation increase in uncertainty is larger and more negative if that economy has a well-developed financial system. Nonetheless, according to table 5 a financially developed economy is associated with smaller uncertainty levels.

Furthermore, as table 5 reports, the average level of uncertainty is negatively correlated with financial development with least financially developed countries facing largest uncertainty levels and vice versa. The volatility of uncertainty is also negatively correlated with financial development. Therefore, financially less-developed countries suffer higher uncertainty levels and greater fluctuations in uncertainty as opposed to more financially developed countries.

We also do a similar analysis using World Bank classification of income groups and test if income level changes the sensitivity of economy to uncertainty. We take a similar approach as we did with financial development quartiles and find the results are fairly similar to how financial development affects the sensitivity of economy to uncertainty. Note that a high-income economy suffers the most from one standard deviation rise in uncertainty. Indeed, such a rise drops productivity level by about 10%.

As evident in table 5, The summary statistics conditional on income group also generally shows similar pattern to that on financial development. Additionally, some differences between the two effects worth being pinpointed. Income group has only a negative impact on the production sensitivity of uncertainty in high-income countries. However, unlike financial development, it shows no sizable effect for the other three groups. The negative correlation between income group and uncertainty level is also evident.

| | $\text{un}^{st}$ | |
|---|---|---|
| FD Quartile | mean | S.D. |
| 1 | 0.76 | 1.18 |
| 2 | 0.21 | 1.11 |
| 3 | 0.26 | 1.13 |
| 4 | -0.31 | 0.69 |
| Total | 0.00 | 1.00 |
| Observations | 1386 | |

(a) Financial development

| | $\text{un}^{st}$ | |
|---|---|---|
| Income Group | mean | sd |
| 1 | 0.85 | 0.98 |
| 2 | 0.61 | 1.37 |
| 3 | 0.11 | 0.92 |
| 4 | -0.34 | 0.66 |
| Total | 0.00 | 1.00 |
| Observations | 1434 | |

(b) Income groups

Table 5: Mean and standard deviation of uncertainty in different quartiles of financial development and different income levels

# 4 Robustness

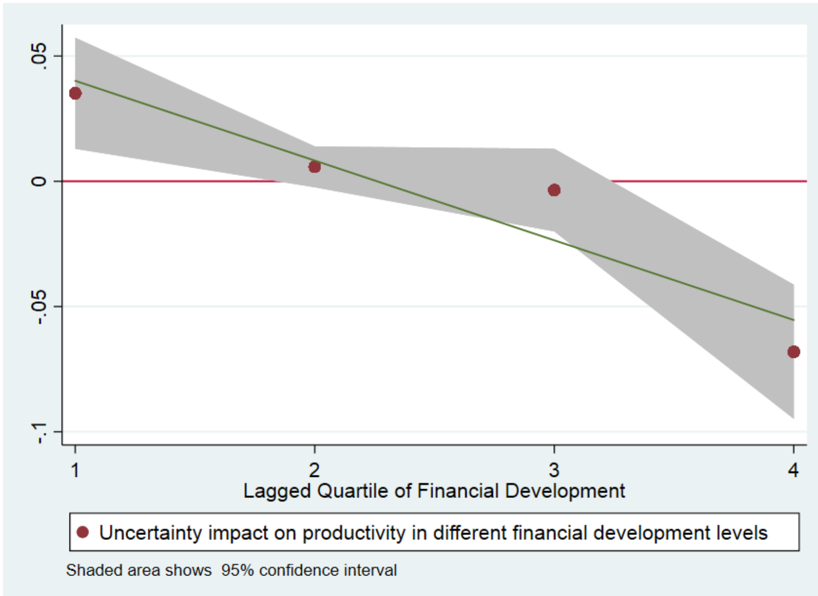
To check for the robustness of our results, we use different measures of uncertainty, which we explained in the Data section. Table 6 evaluates the robustness of uncertainty impact on relative GDP per capita by using different uncertainty measures in our econometric model 1. The first column of table 6 is similar to the fifth column of table 3 in which a pooled OLS regression is estimated. The other three columns of table 6 estimate a similar model but using other uncertainty measures. As evident from the table, the impact of uncertainty is negative and significant for all uncertainty measures. The sensitivity of relative production, however, depends on the selected measures and ranges from -0.8% to -3.1%.

Table 7 evaluates the robustness of uncertainty impact on relative productivity by using different uncertainty measures in the econometric model 2. The first column of table 7 is similar to the third column of table 4 in which a pooled OLS regression is estimated. The next three columns of table 7 estimate the impact of other uncertainty measures on relative productivity using the same econometric model. Consistent with table 6 results, the impact of uncertainty on relative productivity is negative and significant for all uncertainty measures. The extent of impact is, nonetheless, dependent on uncertainty measure selection and ranges from -1.9% to -8.5%.

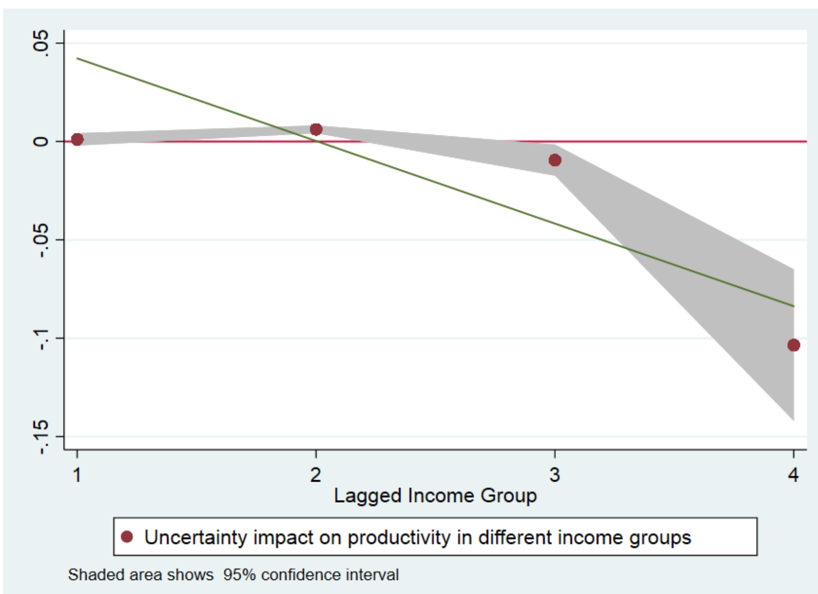
Lastly, we did the entire analysis for the less polished dataset which includes observations in which relative GDP per capita or relative capital per capita are less than 0.01 (adding more than 10% to the number of observations). Even in this case, the results are similar to the ones presented in the paper.

# 5 Conclusions

In this paper we study the impact of macroeconomic uncertainty on economic development and income differences. We construct both macroeconomic uncertainty and




(a) Financial development exacerbates the impact of uncertainty on productivity




(b) Being economically developed exacerbates the impact of uncertainty on productivity

Figure 1: Uncertainty impact on productivity in different development stages

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | $y^r$ | $y^r$ | $y^r$ | $y^r$ |
| $un^{st}$ | -0.0158*** | | | |
| | (-3.40) | | | |
| $un^{ypc}$ | | -0.0245*** | | |
| | | (-3.67) | | |
| $un^{ypl}$ | | | -0.0311*** | |
| | | | (-3.96) | |
| $un^{mc}$ | | | | -0.00804** |
| | | | | (-2.48) |
| $k^r$ | 0.819*** | 0.825*** | 0.833*** | 0.814*** |
| | (73.05) | (78.99) | (78.98) | (72.25) |
| $h^r$ | 0.396*** | 0.367*** | 0.342*** | 0.414*** |
| | (10.33) | (11.05) | (10.19) | (10.98) |
| i | -0.000526 | -0.000343 | -0.000292 | -0.000505 |
| | (-0.88) | (-0.67) | (-0.55) | (-0.87) |
| R&D | -0.0270*** | -0.0248*** | -0.0278*** | -0.0230*** |
| | (-5.41) | (-5.30) | (-5.93) | (-4.67) |
| Constant | -0.233*** | -0.226*** | -0.207*** | -0.248*** |
| | (-7.09) | (-8.04) | (-7.21) | (-7.70) |
| Observations | 632 | 716 | 684 | 650 |
| Adjusted $R^2$ | 0.965 | 0.968 | 0.969 | 0.966 |
| p | 0 | 0 | 0 | 0 |

$z$ statistics in parentheses

$^{*}$ $p < 0.1$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$

Table 6: Robustness check- the impact of different uncertainty measures on relative GDP per capita
Look at tables 1 and 2 for variable definitions

relative development variables to analyze the relationship of these two phenomena. We consider U.S. economy as the reference point and compute development levels relative to that of US.

We show uncertainty has a statistically significant and negative impact on a country's relative development. In fact, one standard deviation rise in uncertainty drops GDP per capita by about %1.5 relative to the US economy. We show this impact is not channeled through investment expenditures to the economy. It may be partially channeled through R&D expenditures, though. We compute a country-specific measure of productivity which takes into account the differences in production elasticities of capital and labor (according to table 8) and show uncertainty indeed affects productivity more severely.

Finally, we tackle the question that whether financial development or income level mitigate the impact of uncertainty. Surprisingly, we find that they both actually exacerbate it. We divide our sample into four quartiles of financial development with fourth quartile being the most financially developed sub-group. We find the fourth

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| | A$^r$ | A$^r$ | A$^r$ | A$^r$ |
| un$^{st}$ | -0.0350*** | | | |
| | (-3.49) | | | |
| un$^{ypc}$ | | -0.0787*** | | |
| | | (-5.56) | | |
| un$^{ypl}$ | | | -0.0859*** | |
| | | | (-5.06) | |
| un$^{mc}$ | | | | -0.0191*** |
| | | | | (-2.71) |
| k$^r$ | 0.672*** | 0.664*** | 0.661*** | 0.663*** |
| | (27.72) | (29.95) | (29.05) | (27.07) |
| h$^r$ | 0.214** | 0.238*** | 0.192*** | 0.263*** |
| | (2.58) | (3.37) | (2.65) | (3.21) |
| i | -0.00424*** | -0.00424*** | -0.00415*** | -0.00416*** |
| | (-3.27) | (-3.89) | (-3.63) | (-3.30) |
| R&D | 0.0293*** | 0.0346*** | 0.0318*** | 0.0369*** |
| | (2.71) | (3.49) | (3.14) | (3.45) |
| Constant | -0.0265 | -0.0654 | -0.0277 | -0.0629 |
| | (-0.37) | (-1.10) | (-0.45) | (-0.90) |
| Observations | 632 | 716 | 684 | 650 |
| Adjusted $R^2$ | 0.834 | 0.851 | 0.849 | 0.835 |
| p | 0 | 0 | 0 | 0 |

$z$ statistics in parentheses

$^{*}$ $p < 0.1$, $^{**}$ $p < 0.05$, $^{***}$ $p < 0.01$

Table 7: Robustness check- the impact of different uncertainty measures on relative productivity
Look at tables 1 and 2 for variable definitions

quartile is in fact more sensitive to uncertainty. That is, one standard deviation rise in uncertainty has a larger negative impact in more financially developed economies. We do a similar exercise this time using World Bank's classification of income groups and find consistent results.

# 6 Appendix

We construct an uncertainty quartile variable using our measure of uncertainty and investigate the important statistics ( mean and standard deviation) of our variables of interest in each uncertainty quartile. Table 8 reports the results.

The table shows that higher relative production per capita, physical capital per capita, human capital, productivity, and financial development are associated with

| UQ | | $y^r$ | $k^r$ | $h^r$ | $A^r$ | $\alpha$ | i | R&D | FD |
|---|---|---|---|---|---|---|---|---|---|
| =1 | | | | | | | | | |
| | mean | 0.59 | 0.68 | 0.84 | 0.60 | 0.46 | 23.24 | 1.70 | 95.00 |
| | S.D. | 0.40 | 0.47 | 0.11 | 0.40 | 0.09 | 6.35 | 1.07 | 51.47 |
| =2 | | | | | | | | | |
| | mean | 0.44 | 0.56 | 0.81 | 0.50 | 0.50 | 24.61 | 1.37 | 74.11 |
| | S.D. | 0.39 | 0.51 | 0.12 | 0.42 | 0.11 | 7.35 | 1.03 | 50.05 |
| =3 | | | | | | | | | |
| | mean | 0.25 | 0.32 | 0.73 | 0.28 | 0.51 | 24.33 | 0.82 | 54.52 |
| | S.D. | 0.31 | 0.41 | 0.12 | 0.36 | 0.11 | 6.10 | 0.68 | 37.85 |
| =4 | | | | | | | | | |
| | mean | 0.17 | 0.24 | 0.72 | 0.19 | 0.51 | 25.29 | 0.67 | 48.30 |
| | S.D. | 0.24 | 0.34 | 0.12 | 0.28 | 0.10 | 8.14 | 0.73 | 36.67 |
| Total | | | | | | | | | |
| | mean | 0.36 | 0.48 | 0.78 | 0.43 | 0.50 | 24.34 | 1.19 | 67.80 |
| | S.D. | 0.38 | 0.48 | 0.13 | 0.41 | 0.11 | 7.05 | 1.00 | 48.02 |
| Observations | 1434 | | | | | | | | |

Table 8: Summary Statistics of Important Variables Conditional on Uncertainty Quartiles
$UQ$ : Uncertainty Quartiles ( 1 shows the lowest uncertainty quartile)
Look at table 2 for other variable definitions

lower uncertainty levels, i.e. these variables are all negatively correlated with uncertainty. These results are not surprising as better developed economies tend to manage risks better, thereby decreasing uncertainty levels.

Another interesting feature is that capital gain share in production ($\alpha$) is higher for more uncertain economies. Investment share of GDP, however, is largely uncorrelated to uncertainty quartiles. Its mean and standard deviation do not change in different uncertainty quartiles. In contrary to most of the literature, it suggests that uncertainty impact does not transmit through investment channel.

Table 8 also reports that higher R&D levels are associated with economies with lower uncertainty levels. That is, R&D is negatively correlated with uncertainty, meaning that lower risks in the aggregate economy increases the incentives to invest in R&D so to improve productivity growth.

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