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Abstract

This paper examines the effects of economic volatility on global sustainability in a dynamic panel data model allowing for error cross section dependence. It finds that output volatility and financial market volatility exert strong negative impacts on sustainable development, with the impacts exacerbated in some subsamples such as higher energy intensity countries and lower trade share countries. The paper also identifies a financial development channel through which output volatility impedes global sustainability, highlighting the interaction between global financial markets and the wider economy as a key factor influencing the low carbon development path. The finding is significant for the conduct of macroeconomic and environmental policies in an integrated global green economy.

Keywords: Output Volatility; Financial Market Volatility; Global Sustainability; Genuine Savings; Cross Section Dependence

JEL Classification: E32; O11; O16

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1 Introduction

In the 1990s the world economy grew at an averaged rate of 2.7 percent per annum, while in the 21st century it has exhibited an exceptional performance, reaching 4.5 percent per annum by the end of 2007.[1] Following the long period of economic booms, the world economy, especially developing economies, experienced considerable unstable growth, severe crises, and typically a period of uncertainty and volatility. On the other hand, climate change has become the most severe global challenge of our age, which is in large part due to human activities (IPCC, 2001).[2] From 1981 to 2005, some 60 per cent of the world's ecosystem have been considered degraded or unsustainably exploited (Barbier, 2009). This poses an important question: could economic volatility lead countries down an unsustainable path?

Over the last decades, volatility, as an independent research area, has moved on from a second-order research area to currently "occupy a central position in development economics" (Aizenman and Pinto, 2005). In today's integrated global markets, every major financial crisis has global repercussions. Together with unstable macro policies and political instability, financial crises are among the main sources of endogenous volatility (Wolf, 2005). Similar to the Asian financial crisis which spread quite rapidly across seven countries of the region after the outburst of the crisis in Thailand in July 1997, the global financial crisis of 2007-2009 has been characterized by incredible speed at which volatility spread around the global financial markets. In particular almost every stock market across the globe went through the episodes of volatility outbursts since the end of 2007.

Breaking out against the background of other looming crises, for example, climate crisis, fuel crisis, and food crisis, the financial crisis of 2007-2009 has caused enormous damage to the world economy and resulted in the most severe global recession in generations.[3] Since the economy traditionally de-

[1] Annual data taken from the World Bank World Development Indicators (2009).

[2] The average global surface temperature has increased by 0.8°C in the past century and 0.6°C in the past three decades (Hansen et al., 2008).

[3] A recent ADB report by Loser (2009) shows that the financial assets around the world may have fallen in value by more than US$50 trillion during 2008, a loss equivalent to almost a year's worth of world economic output. According to IMF (2009), US GDP and euro-area GDP contracted by about 4% and 5% in 2008, respectively.

pends on low energy efficiency and unsustainable use of natural resources, any dramatic changes in demand for goods and manufacturing associated with output volatility and financial crisis will inevitably lead to the wastes of natural resources and a high degree of climate risk. Lin (2009) points out that the current economic downturn is "possibly turning a short-run macroeconomic adjustment into a long-term development problem". However, the empirical evidence on the impact of economic volatility on the long-run sustainable development has been as yet sparse.

This paper takes up the issue of whether economic volatility has a damaging effect on global sustainability. It carries out a dynamic panel data study based on data for 122 countries between 1978-2007 and makes use of the genuine savings or adjusted net savings to measure sustainability. To address the issue of cross country dependence driven by the increases in international trade and private capital flows in recent decades, this research considers a common factor structure in the error term, to fully take into account the effects of global shocks which potentially cause error dependence across countries. More specifically, it applies the system Generalized Method of Methods (GMM) method adjusted to allow for error cross section dependence due to Sarafidis *et al.* (2009).

This paper finds that output volatility exerts a strong negative impact on sustainable development, with the impact exacerbated in low income countries, higher energy intensity countries and lower trade share countries. The effect of financial market volatility on global sustainability has also been shown to be significantly negative, especially for the higher energy intensity countries and lower trade share countries. The resilience of those countries to financial crisis and economic volatility will no doubt play an important role in building a low carbon global economy. Therefore, understanding the nature of volatility and how to manage its consequences should be of considerable interest to governments of those countries, especially developing countries. Rather than an investment channel, this research also finds that private credit ratio acts as a financial channel through which output volatility impedes global sustainability. This highlights the role of the interaction between global financial markets and the wider economy in promoting global sustainability.

This paper contributes to the literature in several dimensions. First, it explores different dimensions of economic volatility, including output volatility and financial market volatility. Second, it allows for the possibility of error cross section dependence and tries to correct for the issues of endogeneity and unobserved country-specific effects. Third, it is significant for the conduct of macroeconomic and environmental policies in an integrated global green economy in the sense that development strategies and programs should take adequate account of the state of natural resources, including forests, soils, freshwater and fisheries, on which future growth is dependent.

The remainder of the paper proceeds in section 2 to review the literature. Section 3 describes the data and outlines the methodology of the system GMM estimation without and with cross section dependence. Section 4 presents the empirical results. Section 5 concludes.

2 Volatility, Growth and Sustainability

This section sketches the theoretical and empirical research in this field, especially on the link between output volatility and growth. Volatility is a normal oscillation around a particular economic variable and usually measured by a standard deviation of that economic variable over some historical period. It "provides a measure of the possible variation or movement in a particular economic variable or some function of that variable, such as growth rate" (Aizenman and Pinto, 2005).[4] Research on the link between output volatility and long-run growth has met with substantial controversies.

Theoretically, one line of research finds that volatility is positively related to growth. Sandmo (1970) and Ghosh and Jonathan (1997) argue that, when households are more uncertain about their future income due to higher macroeconomic volatility they tend to save more of their money for precautionary reasons. The increases in savings lead to higher levels of investment, and therefore higher growth rates. In a two-sector learning-

[4]For the growth rates of GDP, Wolf (2005) defines normal volatility as "the difference between the 25th and 75th percentile of the growth rate distribution", in contrast to the extreme volatility or crisis volatility which are defined as "two sequential years of negative output growth".

or-doing model of endogenous growth, Canton (2002) claims that volatility exerts a positive effect on growth via the accumulation of human capital. On the contrary, the other line of research supports a negative impact of volatility on growth. For example, Kharroubi (2007) illustrates that in the presence of credit constraints and moral hazard when long-term financial contracts are imperfectly enforceable, a bias towards short-term debt could generate maturity mismatches between assets and liabilities and result in liquidity crises. Based on this framework, this study shows that two sources of volatility, normal volatility and abnormal volatility, have independent negative effects on the averaged growth rate of GDP per capita; furthermore the negative growth effects of two sources tend to reinforce each other. Based on a two-period overlapping generations with two types of technologies, the model by Aysan (2007) demonstrates how volatility reduces growth by aggravating the financial market imperfections. More specifically, the model predicts that greater volatility induces financial intermediaries to charge higher interest rates, and therefore increases the cost of borrowing associated with capital market imperfections. The higher cost deters people from obtaining and using more productive technologies, which is detrimental to growth.

Empirically, Kormendi and Meguire (1985) and Grier and Tullock (1989) find evidence that output volatility promotes growth, among others. However, the majority of cross country studies suggest that economic volatility negatively affects long-run growth, especially for the poorer countries.[5] Starting with Ramey and Ramey (1995), the study of the negative effect of volatility on growth has flourished, for example, Hnatkovska and Loayza (2005) and Loayza *et al.* (2007). Ramey and Ramey (1995) show that countries with higher output volatility tend to have lower economic growth, by using a sample of 92 countries over 1960-1985 and a sample of OECD countries over 1950-1988. Hnatkovska and Loayza (2005), employing data for 79 countries over 1960-2000, find that a significantly negative link exists between macroeconomic volatility and long-run growth, depending on various

[5] Koren and Tenreyro (2007) find that poor countries tend to specialize in fewer and more volatile sectors, and are therefore more exposed to the frequent and severe aggregate shocks.

structural country characteristics including country's overall level of development, the extent of financial depth, the level of institutional development and the degree of fiscal policy procyclicality, but not the degree of trade openness. They also find evidence that macroeconomic volatility exerts a harmful causal effect on economic growth, which is particularly so for low-income and middle income countries. Loayza *et al.* (2007) further point out that macroeconomic volatility has a negative effect on output growth, future consumption and thus welfare, through its links with various economic, political and policy-related uncertainty and with "the tightening of binding investment constraints". In terms of the channels through which volatility exerts a damaging effect on growth or long-run development, Ramey and Ramey (1995) emphasize the role of the level of investment while Aysan (2007) supports for the productivity of investment rather than the level of investment. A number of transmission channels have been discussed by Wolf (2005), including factor accumulation, domestic finance, trade, capital mobility, and political institutions.

Economic development has been traditionally based on low energy efficiency and unsustainable use of our ecological commons. Given the ecological limits of our planet, transition to a low-carbon economy has been believed to be significant for our future, which will change our industrial landscape and contribute to significant energy and resource savings and long-term development. Since high growth performances do not necessarily lead to high levels of development, in comparison to output growth, policy makers have increasingly laid emphasis upon sustainable development as the primary national objective, especially for developing countries.

The concept of sustainable development or sustainability was created explicitly to reflect the development path in which economic growth and industrialization can be achieved without environmental damage. The definition of sustainable development has evolved over the decades. It was defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs"(World Commission on Environment and Development, 1987). Pezzey (1992) defines it as a development path based on net wealth accumulation where the rents from natural resource depletion are being transformed to alternative forms of wealth and saved for the future, by which the change in the real values of net wealth is non-negative and the per capita welfare is not declining. Sustainability has been typically regarded as having three dimensions or "three pillars", namely environmental, social and economic sustainability, which are not mutually exclusive and can be mutually reinforcing (United Nations, 2005).

Apart from reducing growth rates and leading to occasional recessions and rising unemployment, volatility often results in prevailing famines, critical riots, persistent stagnation and unsustainable consumption and investment in developing countries. However, empirical evidence on the impact of macroeconomic volatility on sustainable development has been limited. This research will contribute to this emerging line of research.

3 Data and Methodology

3.1 The Data

This research studies whether economic volatility has any significant impacts on sustainable development, controlling for the growth rate of GDP per capita, gross national income per capita, and age dependence ratio.[6] Appendix Table 1 contains the description and sources of these variables.

The dependent variable is the genuine saving or adjusted net saving, denoted by $GENSAV$. Genuine saving, the widely-used sustainability indicator, is the true saving rate in an economy in terms of creating and maintaining total wealth, which is inclusive of manufactured capital, human capital, and natural capital.[7] Based on standard national accounting

[6] We also consider life expectancy ratio and urbanization rate as controlling variables, but we find no evidence for them. Data for the life expectancy at birth (total years) and urban population (% of total) are taken from the World Bank World Development Indicators Database (2009).

[7] As synonymous with genuine saving, Arrow *et al.* (2004) use genuine investment to measure sustainability. Genuine investment is the total values of changes in genuine wealth at constant accounting prices, which includes manufactured capital assets, human capital and natural capital. It may also depend on the level of technology. In assessing the measure of genuine investment, Arrow *et al.* (2004) also take into account the impacts of population growth and technological change; however, their results are sensitive to the choices of GDP-wealth ratio.

conventions, genuine saving takes into account the investments in human capital, depletion of natural resources and pullution damages[8]. The data for the adjusted net savings, excluding particulate emission damage (% of Gross National Income), are taken from the World Bank World Development Indicators Database (2009). In the regression below we use the 3-year averages from 1978 to 2007 of the natural logarithm of one plus the adjusted net savings divided by 100, $\log(1 + GENSAV/100)$.

This analysis mainly focuses on the output volatility and financial market volatility. The measure of output volatility, denoted by VGR, is defined as the standard deviation over 3-year interval from 1978 to 2007 of the natural logarithm of one plus the annual growth rate of GDP per capita (GR) divided by 100, $\log(1+GR/100)$. The data for the annual growth rate of GDP per capita are from the World Bank World Development Indicators Database (2009).

The financial volatility in terms of private credit volatility is denoted by $VPRIVO$. It is measured by the standard deviation over 3-year interval from 1978 to 2007 of the logarithm of one plus the private credit ratio ($PRIVO$), $\log(1+PRIVO)$. The private credit ratio captures general financial intermediary activities provided to the private sectors. More specifically, it is the ratio to GDP of the credit issued to the private sectors by banks and other financial intermediaries, excluding credit issued to government, government agencies and public enterprises. The data for private credit ratio are from the World Bank Financial structure and Financial Development Database (2009).

Two potential channels will be investigated, namely KI and $PRIVO$. KI, the investment channel, is the investment share of real GDP per capita (RGDPL), taken from the Penn World Table 6.3 due to Heston *et al.* (2009). In the regression we use the logarithm of one plus the investment share of real GDP per capita (RGDPL) divided by 100, $\log(1 + KI/100)$. $PRIVO$, the financial channel, is the private credit ratio as explained above. We use the

[8] More specifically, genuine savings deduct the value of depletion of the underlying resource asset and pollution damages from gross national savings, while adding the current educational spending to gross national savings, since this spending may be considered as an investment in human capital (World Bank Environmental Indicators, 2002).

logarithm of one plus private credit ratio in the analysis, $\log(1 + PRIVO)$.

We control for GDP growth rate (GR), gross national income per capita ($GNIPC$), and age dependency ratio (AGE). $GNIPC$ is the 3-year averages from 1978 to 2007 of the logarithm of gross national income per capita, $\log(GNIPC)$. For GR and AGE, this analysis makes use of the 3-year averages from 1978 to 2007 of the logarithms of one plus the annual growth rate of GDP per capita divided by 100 and age dependency ratio divided by 100, respectively. Data for the annual growth rate of GDP per capita, gross national income per capita and age dependency ratio (dependents to working-age population) are taken from the World Bank World Development Indicators Database (2009).

The whole sample contains 122 non-transition economies over the period 1978-2007 with a maximum of 10 observations per country as listed in the Appendix Table 2. We exclude countries with less than 10 observations during the period studied. We consider three subsamples in this analysis, low income sample, higher energy intensity sample and lower trade share sample. The low income subsample contains 47 low income countries. Information on the classifications of income levels is obtained from the World Bank Global Development Network Database (2002). The higher energy intensity sample contains 56 countries whose averaged final energy intensities over 1978-2007 are above the median value of the averaged final energy intensities. Data on final energy intensity of GDP at purchasing power parities are taken from the Global Energy Market Data (2008) of Enerdata. The lower trade share sample has 67 countries whose averaged trade shares are below the median value of the averaged trade shares over 1978-2007. Data on trade share (% of GDP) are taken from the World Bank World Development Indicators Database (2009).

Figure 1 presents the longer-run evolutions of genuine savings, output volatility and private credit volatility for the whole sample and three subsamples from 1978 to 2007. The figures display the prevailing volatility in the past three decades, especially from the end of 1990s to the beginning of the 21st century after the Asian financial crisis and other regional economic crises. The figures also illustrate an increase of private credit volatility while a decline of output volatility. Figure 2 simply shows the scatter plots

Figure 1.1 Genuine Savings Over Time

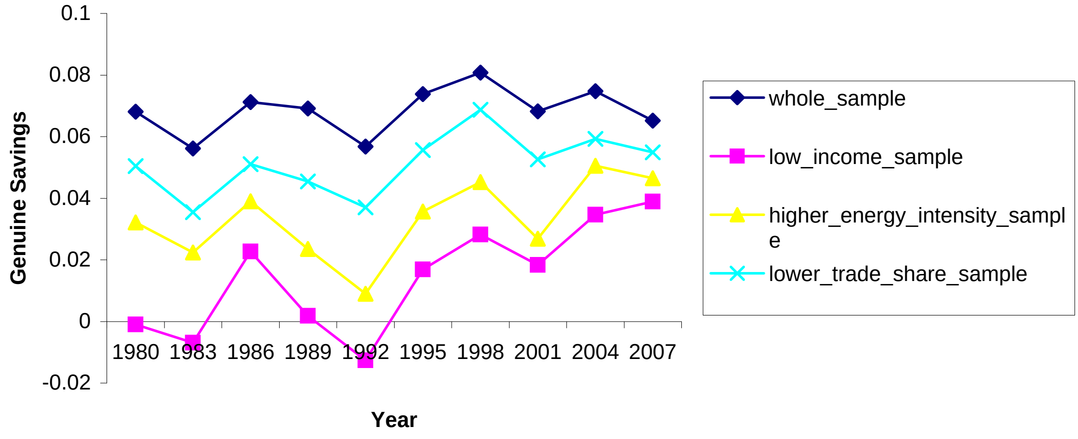


Figure 1.2 Output Volatility Over Time

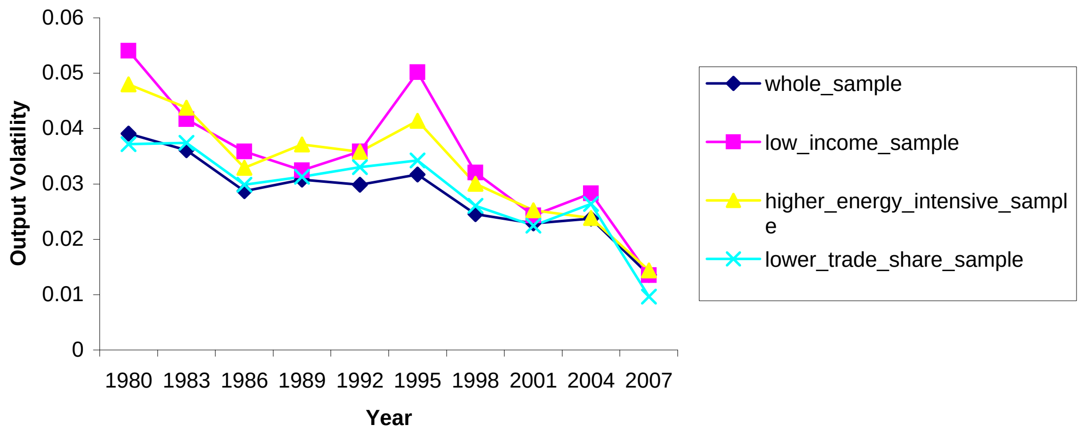


Figure 1.3 Private Credit Volatility Over Time

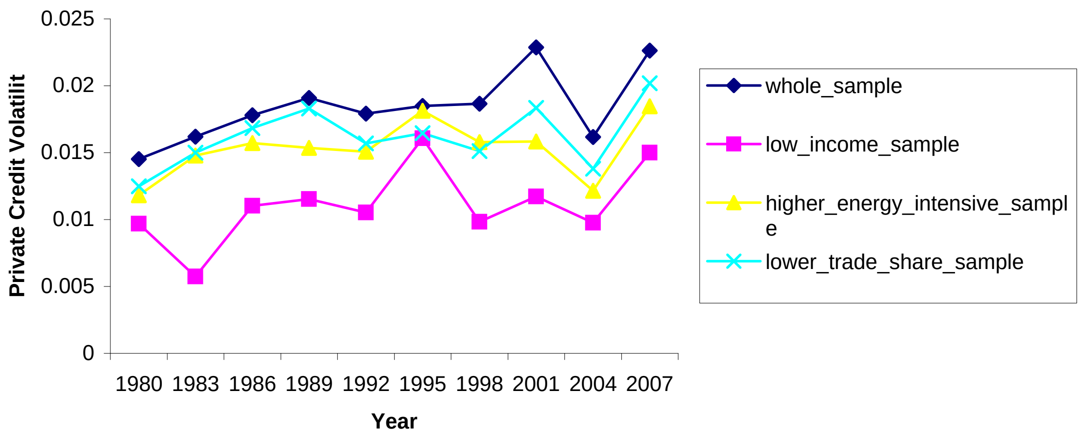
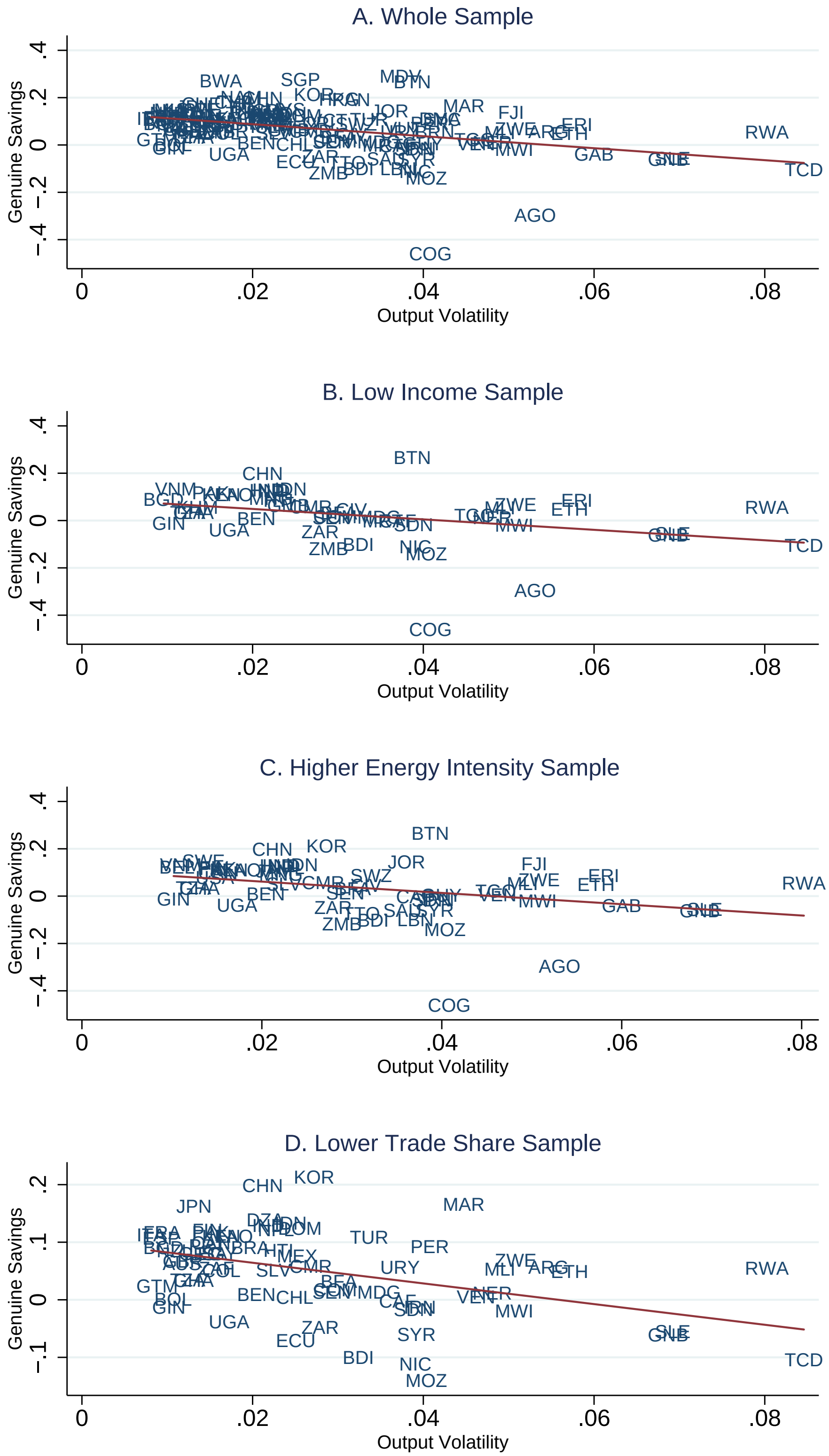


Figure 2: Scatter Plots of Genuine Savings and Output Volatility



Note: Variables and data sources are described in the text.

between genuine savings and output volatility, suggesting a negative association between genuine savings and output volatility for the whole sample and three subsamples.

3.2 Methodology

This section reviews the methods used to study the impact of economic volatility on sustainable development in the context of globalisation. It employs the GMM methods adjusted to allow for error cross section dependence, recently proposed by Sarafidis *et al.* (2009) for a linear dynamic panel model.

In recent decades, the cross country dependence has become an important phenomenon in a globalised world where the existence of common factors, either global, cyclical or seasonal effects, has the potential to cause stronger interactions in the world economy. To allow for error cross section dependence, the following AR(1) model has been found appropriate for this application:

$$\begin{aligned} GENSAV_{it} &= \gamma_i + \alpha GENSAV_{i,t-1} + \beta_1 VOL_{i,t-1} + \beta_2 GR_{i,t-1} + \\ &\quad \beta_3 GNIPC_{i,t-1} + \beta_4 AGE_{it} + \lambda_i^{'} f_t + v_{it} \qquad (1) \\ i &= 1, 2, ..., 122 \text{ and } t = 2, ..., 10 \end{aligned}$$

where VOL denotes the volatility measure, which could be output volatility measures VGR, or private credit volatility measure $VPRIVO$. γ_i is the individual effects. The autoregressive coefficient α is assumed to lie inside the unit circle, $\mid \alpha| < 1$, to ensure the model stability. The coefficients β_1 to β_4 reflect the existence and direction of any specific effect on sustainable development. f_t is a $(r \times 1)$ vector of unobserved time-varying common factors assumed to be nonstochastic and bounded, and λ_i is a vector of factor loadings assumed to be i.i.d., such that $\lambda_i^{'} f_t = \lambda_{i1} f_{t1} + \lambda_{i2} f_{t2} + ... + \lambda_{ir} f_{tr}$ (here r is the number of common factors).[9] The common factors could be either macroeconomic shocks, common technological shocks or environmental

[9] Bai (2009) suggests an interactive effects model including the interaction between factors, f_t, and factor loadings, λ_i, which is more general than an additive effects model, the traditional one-way or two-way fixed effects model. When we take r=2, we have $f_t = (1$

shocks that lead to cross section dependence. The error term v_{it} is the transitory disturbance term, which is assumed to be independently distributed with zero mean and finite variance. v_{it} is assumed to be uncorrelated with the individual effects and common factors, but the correlations between, either individual effects or common factors (f_t and subseqent shocks), and the regressors are possible.

We assume that VOL, GR, and $GNIPC$ are predetermined with respective to v_{it} in the sense that these variables may be correlated with $v_{i,\ t-1}$ and earlier shocks, but is uncorrelated with $v_{i\ t}$ and subsequent shocks. The assumption on these explanatory variables, except for AGE, being predetermined rules out a potential endogeneity bias, but allows for feedbacks from the past realizations of $GENSAV$ to current values of these explanatory variables.

Below is Equation (1) in first differences:

$$\begin{aligned} \Delta GENSAV_{it} &= \alpha \Delta GENSAV_{i,t-1} + \beta_1 \Delta VOL_{i,t-1} + \beta_2 \Delta GR_{i,t-1} + \\ &\quad \beta_3 \Delta GNIPC_{i,t-1} + \beta_4 \Delta AGE_{it} + \lambda_i^{'} \Delta f_t + \Delta v_{it} \qquad (2) \\ i &= 1, 2, ..., 122 \text{ and } t = 3, ..., 10 \end{aligned}$$

where $\Delta GENSAV_{it} = GENSAV_{it} - GENSAV_{i,t-1}$, which applies to ΔAGE_{it}. $\Delta VOL_{i,t-1} = VOL_{i,t-1} - VOL_{i,t-2}$, which also applies to $\Delta GR_{i,t-1}$ and $\Delta GNIPC_{i,t-1}$. $\Delta f_t = f_t - f_{t-1}$ and $\Delta v_{it} = v_{it} - v_{i,t-1}$.

When common factors are assumed to have an identical effect on each cross section unit, a number of methods have been proposed to estimate the dynamic panel data models with a short time dimension, in which first-differencing is used to eliminate the individual effects. Arellano and Bond (1991) propose the first-differenced GMM estimator, denoted by DIF-GMM, which uses all lagged values of dependent variable and independent variables dated from $t-2$ and earlier as suitable instruments for the differenced values of the original regressors, for example, $\Delta GENSAV_{i,t-1}$, $\Delta VOL_{i,t-1}$, $\Delta GR_{i,t-1}$, $\Delta GNIPC_{i,t-1}$, and ΔAGE_{it} in this context.

$\eta_t)^{'}$, $\lambda_i^{'} = (\alpha_i\ 1)$, and $\lambda_i^{'} f_t = \alpha_i + \eta_t$, where α_i and η_t are the individual effect and time effect, respectively.

For simplicity, we let y_{it} denote $GENSAV_{it}$ and let x_{it} be a vector of the independent variables, e.g. $(VOL_{it},\ GR_{it},\ GNIPC_{it}, AGE_{it})$. The moment conditions for errors in differences on which the DIF-GMM estimator is based in this application can be written as,

$$E\left[\left(\begin{array}{c} y_i^{t-2} \\ x_i^{t-2} \end{array}\right)(\Delta v_{it})\right] = 0 \quad (3)$$
$$t = 3, .., 10$$

where $y_i^{t-2} = (y_{i1},\ y_{i2}, ...,\ y_{i,t-2})'$ and $x_i^{t-2} = (x_{i1},\ x_{i2}, ...,\ x_{i,t-2})'$.

The weak instruments problem associated with the DIF-GMM estimator has been widely aware when data are highly persistent. To address this issue, Arellano and Bover (1995) and Blundell and Bond (1998) develop a "system GMM" estimator, denoted by SYS-GMM, by considering a mean stationarity assumption on initial conditions.[10] The additional mean stationarity condition of (y_{it}, x_{it}) enables the lagged first-differences of the series (y_{it}, x_{it}) dated $t-1$ as instruments for the untransformed equations in levels. More specifically, in addition to the moments for errors in differences described above, the SYS-GMM estimator is also based on the additional moments for errors in levels as follows,

$$E\left[\left(\begin{array}{c} \Delta y_{i,t-1} \\ \Delta x_{i,t-1} \end{array}\right)(\gamma_i + v_{it})\right] = 0 \quad (4)$$
$$t = 3, .., 10$$

However, in reality common factors are typically having a differential effect across cross-sectional units, causing heterogeneous error cross section dependence. Sarafidis and Robertson (2009) show that the standard DIF-GMM and SYS-GMM estimators are not consistent in the presence of

[10] Blundell and Bond (2000) show that the joint mean stationarity of the series in the multivariate autoregressive model is a sufficient condition for the additional moment conditions to be valid. Blundell and Bond (1998) argue that, combining the first-differenced equations (with suitably lagged levels as instruments), with levels equations (with suitably lagged first-differences as instruments), the SYS-GMM estimator is expected to have much smaller finite sample bias and greater precision than DIF-GMM estimator in the presence of persistent data.

heterogeneous error cross section dependence, for the standard instruments these estimators rely on with respect to lagged values of the dependent variable, in either levels or first-differences, are invalid.

Under the assumption of heterogeneous error cross section dependence, Sarafidis *et al.* (2009) suggest a consistent first-differenced GMM estimator, denoted by DIF-GMM-C, and a consistent system GMM estimator, denoted by SYS-GMM-C. These two GMM estimators only rely on the partial instruments consisting of the regressors. More specifically, based on the partial moment condition (5) as shown below the DIF-GMM-C estimator is consistent under the assumption of heterogeneous error cross section dependence. This applies to the SYS-GMM-C estimator, which is based on the partial moment conditions (5) and (6) in the following:

$$\begin{aligned} E\left[x_i^{t-2}\Delta v_{it}\right] &= 0 \\ t &= 3,..,10 \end{aligned} \tag{5}$$

$$\begin{aligned} E\left[\Delta x_{i,t-1}(\gamma_i + v_{it}\ )\right] &= 0 \\ t &= 3,..,10 \end{aligned} \tag{6}$$

A new testing procedure for detecting error cross section dependence in a linear dynamic panel model has been proposed by Sarafidis *et al.* (2009). Under the null hypothesis of homogeneous error cross section dependence (CSD), the CSD test enables the examination on whether any error cross section dependence remains after including time dummies. The CSD test is the Sargan's difference tests based on either the two-step first-differenced GMM estimator or two-step system GMM estimator.[11] The finite sample simulation-based results in Sarafidis *et al.* (2009) show the good performance of the CSD test, especially for the version based on system GMM estimator.

[11] The Sargan's difference test statistics based on two-step first-differenced GMM estimator is the difference between the Sargan statistics for DIF-GMM with standard set of moment conditions (3) and the Sargan statistics for DIF-GMM-C using restricted set of moment conditions (5). The Sargan's difference test statistics based on two-step system GMM estimator is the difference between the Sargan statistics for SYS-GMM with standard set of moment conditions (3) and (4) and the Sargan statistics for SYS-GMM-C using restricted set of moment conditions (5) and (6).

To avoid the possible overfitting bias associated with using the full Arellano and Bond (1991) instrument set, this analysis uses restricted instrument sets suggested by Bowsher (2002), who proposes to selectively reduce the number of moment conditions for each first-differenced equation. More specifically, we only use lagged values of y_{it} and x_{it} from $t-2$ to $t-3$ as instruments in this analysis.

4 Empirical Results

This section firstly presents the econometric evidence on whether macroeconomic volatility, either output volatility or financial market volatility, is an impediment to global sustainability. The second subsection then moves on to examine the channels through which volatility adversely affects sustainable development.

Every table contrasts the DIF-GMM and SYS-GMM estimates assuming cross-sectionally independence with their counterparts, DIF-GMM-C and SYS-GMM-C, under the assumption of errors being cross-sectionally dependent.[12] A finite sample correction is made to the two-step covariance matrix using the method due to Windmeijer (2005) for both the first-differenced GMM estimator and system GMM estimator under either assumption. For any GMM estimators, three specification tests are conducted to address the consistency. The first two are the Serial Correlation tests, M1 and M2, which test the null hypothesis of no first-order serial correlation and no second-order serial correlation in the residuals in the first-differenced equation, respectively. Given that the errors in levels are serially uncorrelated, we would expect to find significant first-order serial correlation, but insignificant second-order correlation in the first-differenced residuals. The third is a Sargan test of overidentifying restrictions, which examines the overall validity of the instruments by comparing the moment conditions with their sample analogue. For SYS-GMM and SYS-GMM-C, an additional test, namely the Difference Sargan test denoted by Diff-Sargan, is carried out. The Differ-

[12] Under either assumption, the first-differenced GMM estimates and system GMM estimates in every model have been found to lie between the Within Group estimates, being downwards biased, and the OLS estimates, being upwards biased, for the lagged dependent variable (Bond *et al.*, 2001; Bond, 2002).

ence Sargan test examines the null hypothesis that the lagged differences of the explanatory variables are uncorrelated with the errors in the levels equations due to Blundell and Bond (1998).[13] The new cross-sectional dependence (CSD) tests based on first-differenced GMM estimator and system GMM estimator as explained above are conducted, respectively.[14]

4.1 The Impacts of Volatility on Sustainability

4.1.1 Output Volatility

This subsection studies whether output volatility has led to unsustainability in the economy over the period from 1978 to 2007. Table 1 reports the evidence for the whole sample of 122 countries. Table 2, Table 3 and Table 4 present evidence for the lower income group, higher energy intensity group and the lower trade share group, respectively.

Columns 1 and 2 in Table 1 are concerned about the case of cross-sectional independence, whilst columns 3 and 4 are for the case of cross-sectional dependence. The specification tests indicate that every model is well specified. More specifically, we can reject no first-order serial correlation but cannot reject the hypothesis that there is no second-order serial correlation in any of the four models. The Sargan tests do not signal that the instruments in any of four models are invalid. Under different assumption, both DIF-GMM and DIF-GMM-C suggest a strong negative impact of the output volatility on genuine savings.

The Diff-Sargan tests for SYS-GMM and SYS-GMM-C cannot reject the null of the additional moment conditions being valid, implying that system GMM is a more reliable estimator than the first-differenced GMM in this context. Under different assumption, both SYS-GMM and SYS-GMM-C suggest that the impact of output volatility on global sustainability is negative, but it is significant at 15% level. Both SYS-GMM and SYS-GMM-C also provide evidence that $GNIPC$ and AGE are negatively present in the model within 5% significance level.

[13] The statistic, called an incremental Sargan test statistic, is the difference between the Sargan statistics for DIF-GMM (or DIF-GMM-C) and Sargan statistics for SYS-GMM (or SYS-GMM-C).

[14] For all specification tests in all tables below, reported are the p-values.

Table 1 . Output Volatility and Global Sustainability: 1978-2007 (Whole Sample)

Dependent Variable: $GENSAV_{it}$	Cross-sectional independence		Cross-sectional dependence	
	DIF-GMM	**SYS-GMM**	**DIF-GMM-C**	**SYS-GMM-C**
$GENSAV_{i,t-1}$	0.605	0.710	0.702	0.654
	[0.000]***	[0.000]***	[0.006]***	[0.000]***
$VGR_{i,t-1}$	-0.205	-0.151	-0.250	-0.153
	[0.062]*	[0.118]	[0.040]**	[0.147]
$GR_{i,t-1}$	-0.040	0.089	-0.038	0.161
	[0.870]	[0.505]	[0.886]	[0.220]
$GNIPC_{i,t-1}$	-0.072	-0.038	-0.085	-0.037
	[0.217]	[0.017]**	[0.203]	[0.036]**
AGE_{it}	-0.074	-0.419	-0.114	-0.442
	[0.840]	[0.011]**	[0.788]	[0.032]**
M1	0.02	0.00	0.06	0.01
M2	0.12	0.14	0.11	0.13
Sargan test	0.44	0.68	0.46	0.59
Diff-Sargan test		0.76		0.56
CSD test	0.32	0.60		
Observations	787	910	787	910

Notes: 122 countries over the period of 1978-2007. Global sustainability (GENSAV) is measured by the 3-year averages of genuine savings. Output volatility (VGR) is measured by the standard deviation over 3-year interval of the growth rate of GDP per capita. Controlled variables are the 3-year averages of per capita GDP growth rate (GR), per capita GNI (GNIPC), and age dependence ratio. (AGE). See text for their definitions. Under the assumption of cross-sectional independence first-differenced GMM estimates, denoted by DIFF-GMM, and system GMM estimates, denoted by SYS-GMM, are reported. When cross-sectional dependence is allowed, their counterpartes are reported, DIFF-GMM-C and SYS-GMM-C. Both first-differenced GMM and system GMM results are two-step estimates with heteroskedasticity-consistent standard errors and test statistics; the standard errors are based on finite sample adjustment of Windmeijer (2005). M1 and M2 test the null of no first-order and no second-order serial correlation in first-differenced residuals, respectively. The Sargan tests the overidentifying restrictions for GMM estimators, asymptotically χ^2. Diff-Sargan tests the null of mean stationarity for system GMM estimators in which SYS-GMM or SYS-GMM-C use standard moment conditions. CSD test is to examine the null hypothesis of homogeneous error cross section dependence due to Sarafidis et al. (2009). Robust p values in brackets below point estimates. *, **, *** significant at 10%, 5%, 1%, respectively.

Table 2 . Output Volatility and Global Sustainability: 1978-2007 (Low Income Sample)

Dependent Variable:	Cross-sectional independence		Cross-sectional dependence	
$GENSAV_{it}$	DIF-GMM	SYS-GMM	DIF-GMM-C	SYS-GMM-C
$GENSAV_{i,t-1}$	0.694	0.768	0.210	0.766
	[0.000]***	[0.000]***	[0.655]	[0.006]***
$VGR_{i,t-1}$	-0.246	-0.248	-0.168	-0.286
	[0.054]*	[0.073]*	[0.293]	[0.022]**
$GR_{i,t-1}$	-0.088	-0.082	0.164	-0.186
	[0.770]	[0.576]	[0.709]	[0.558]
$GNIPC_{i,t-1}$	-0.061	-0.100	0.036	-0.113
	[0.268]	[0.023]**	[0.812]	[0.187]
AGE_{it}	-0.351	-0.686	0.255	-0.720
	[0.448]	[0.014]**	[0.763]	[0.020]**
M1	0.02	0.01	0.80	0.09
M2	0.14	0.15	0.12	0.13
Sargan test	0.55	0.90	0.62	0.83
Diff-Sargan test		0.97		0.78
CSD test	0.34	0.72		
Observations	282	331	282	331

Notes: The low income sample contains 47 low income countries. See Table 1 for more notes.

Table 3 . Output Volatility and Global Sustainability: 1978-2007 (Higher Energy Intensity Sample)

Dependent Variable: $GENSAV_{it}$	Cross-sectional independence		Cross-sectional dependence	
	DIF-GMM	SYS-GMM	DIF-GMM-C	SYS-GMM-C
$GENSAV_{i,t-1}$	0.596	0.662	0.866	0.619
	[0.000]***	[0.000]***	[0.059]*	[0.001]***
$VGR_{i,t-1}$	-0.240	-0.218	-0.280	-0.235
	[0.003]***	[0.028]**	[0.005]***	[0.051]*
$GR_{i,t-1}$	-0.004	0.043	0.016	0.076
	[0.987]	[0.823]	[0.948]	[0.699]
$GNIPC_{i,t-1}$	-0.077	-0.053	-0.092	-0.057
	[0.249]	[0.066]*	[0.141]	[0.111]
AGE_{it}	0.130	-0.597	0.157	-0.618
	[0.735]	[0.018]**	[0.701]	[0.069]*
M1	0.02	0.01	0.11	0.02
M2	0.48	0.55	0.49	0.57
Sargan test	0.90	0.98	0.86	0.96
Diff-Sargan test		0.90		0.87
CSD test	0.64	0.74		
Observations	348	406	348	406

Notes: The higher energy intensity sample contains 56 countries whose averaged final energy intensities over 1978-2007 are above the median value of the averaged final energy intensities. See Table 1 for more notes.

Table 4 . Output Volatility and Global Sustainability: 1978-2007
(Lower Trade Share Sample)

Dependent Variable: $GENSAV_{it}$	Cross-sectional independence		Cross-sectional dependence	
	DIF-GMM	SYS-GMM	DIF-GMM-C	SYS-GMM-C
$GENSAV_{i,t-1}$	0.607	0.623	0.746	0.628
	[0.000]***	[0.000]***	[0.000]***	[0.011]**
$VGR_{i,t-1}$	-0.118	-0.179	-0.140	-0.212
	[0.413]	[0.187]	[0.406]	[0.118]
$GR_{i,t-1}$	0.162	0.162	0.096	0.132
	[0.441]	[0.282]	[0.703]	[0.402]
$GNIPC_{i,t-1}$	-0.031	-0.034	-0.050	-0.046
	[0.609]	[0.061]*	[0.328]	[0.026]**
AGE_{it}	-0.016	-0.440	-0.022	-0.502
	[0.965]	[0.047]**	[0.947]	[0.082]*
M1	0.01	0.01	0.02	0.05
M2	0.48	0.55	0.42	0.55
Sargan test	0.18	0.81	0.09	0.44
Diff-Sargan test		1.00		0.99
CSD test	0.61	1.00		
Observations	461	530	461	530

Notes: The lower trade share sample contains 67 countries whose averaged trade shares (% of GDP) over 1978-2007 are below the median value of the averaged trade shares. See Table 1 for more notes.

The CSD tests based on first-differenced GMM estimator and system GMM estimator fail to reject the null of homogeneous error cross section dependence for both the whole sample and the subsamples. However, under certain circumstances this test might lack power because it is based on the overidentifying restrictions test statistic, and accordingly this result should be interpreted with caution. Next subsection provides evidence for such a cross section dependence to exist when financial market volatility is investigated.

In principle, the first-differenced GMM and system GMM estimates impose homogeneity on all slope coefficients, under assumption of either the cross-sectional independence or cross-sectional dependence. One concern over the GMM estimates is that these parameters may be heterogeneous across countries. To address this concern we simply need to look into some subsamples, which are more homogeneous. In what follows we turn to three subsamples with results presented in Table 2, Table 3 and Table 4, respectively.

Table 2 focuses on the subsample of 47 low income countries. Under either assumption, the patterns of the specification tests including M1, M2 and Sargan tests, indicate that all four models are well-specified. Diff-Sargan test further shows that system GMM is a more reliable estimator than the first-differenced GMM for this case. Both SYS-GMM and SYS-GMM-C provide evidence for a strong negative impact going from output volatility to genuine savings in the low income sample.

Table 3 looks at the subsample of 56 higher energy intensity countries. These are countries having averaged final energy intensities above the median value of the averaged final energy intensities over 1978-2007. Under different assumption, both first-differenced GMM, DIF-GMM and DIF-GMM, and system GMM, SYS-GMM and SYS-GMM-C, consistently suggest a strong negative impact of output volatility on sustainable development in these countries.

In Table 4 we turn to the subsample of 67 lower trade share countries. These countries in general have averaged trade shares over GDP under the median value of the averaged trade shares over 1978-2007. The specification tests continue to show that the models in four columns are well-specified and the system GMM estimator is preferable to first-differenced GMM estimator. Both SYS-GMM and SYS-GMM-C find a negative impact of output volatility on sustainable development, significant at 19% and 12% levels. Under different assumption, both SYS-GMM and SYS-GMM-C estimates confirm that both $GNIPC$ and AGE significantly enter the model.

In general, this subsection provides evidence that output volatility exerts an adverse effect on global sustainability, especially for the low income countries, higher energy intensity countries and lower trade share countries.

4.1.2 Financial Market Volatility

This subsection turns to financial market volatility in terms of private credit volatility ($VPRIVO$). Table 5 reports evidence for the whole sample, while Table 6 and Table 7 present results for the higher energy intensity sample and lower trade share sample.[15]

Table 5 reports evidence for the whole sample of 122 countries. Serial correlation tests, M1 and M2, suggest that we can reject the hypothesis of no first-order serial correlation but cannot reject no second-order serial correlation in any of the four models. The Sargan tests cannot reject the null that the instruments in any of four models are valid. The Diff-Sargan tests for SYS-GMM and SYS-GMM-C cannot reject the null that the additional moment conditions are valid, supporting system GMM estimator for the more reliable estimator for this context. Based on system GMM estimator, the CSD test clearly rejects the null of homogeneous cross-sectional dependence.[16] This points to the importance of taking into account the issue of cross-sectional dependence for this context and suggests that the SYS-GMM-C is a consistent estimator. The SYS-GMM-C estimates provide strong evidence on a negative effect of private credit volatility on global sustainability.

According to Sarafidis and Robertson (2009), the standard SYS-GMM estimator is not consistent in the presence of heterogeneous error cross section dependence. Ideally, one would expect to see Sargan's test for SYS-

[15] We find no significant evidence for the low income sample.

[16] The CSD test based on first-differenced GMM estimator rejects the null at 13% significant level.

GMM rejecting the null while Sargan's test for SYS-GMM-C failing to reject the null and CSD test rejecting the null. However, the p-value of Sargan's test for SYS-GMM is 0.49, indicating that SYS-GMM is actually consistent in this context. On way to explain this contradiction is that Sargan's test typically has low power.

An interesting observation is that CSD test will reject the null when the estimated coefficients for at least one regressor, except for the lagged dependent variable, are significantly different. For example, for $VPRIVO_{i,t-1}$ the SYS-GMM estimate is -0.170 while the SYS-GMM-C estimate is -0.234. Similar observation can be found in Table 8 below where the SYS-GMM estimate for $GR_{i,t-1}$ is 0.180 while SYS-GMM-C estimate is 0.244 (for financial development channel).

For the whole sample, the CSD test clearly rejects the null. Since parameter heterogeneity is a potential cause of cross-sectional dependence, it might be expected that for the subsamples below the CSD test fails to reject the null.

Table 6 reports evidence for the subsample of 56 higher energy intensity countries. Neither Diff-Sargan test nor CSD test based on system GMM can reject the null, calling for the attention to be paid to the SYS-GMM estimates. The SYS-GMM estimates confirm the strong negative impact of private credit volatility ($VPRIVO$) on sustainable development in these countries. In Table 7 we present evidence for the subsample of 67 lower trade share countries. Under different assumption, both DIF-GMM and DIF-GMM-C estimates provide strong evidence for the significant effect of private credit volatility ($VPRIVO$) on sustainable development, but system GMM estimates suggest that the effect is significant at about 18% level.

This subsection finds a strong negative impact of private credit volatility on global sustainability in both the whole sample and two subsamples, higher energy intensity countries and lower trade share countries. This finding points to the possible damaging consequences of credit volatility for the economy as a whole, consistent with what has happened during global financial crisis of 2007-2009. In the aftermath of the subprime crisis and housing bubbles burst in mid-2007, worldwide credit crunch became a major economic phenomenon, triggering a sustained period of stress and instability in

Table 5. Financial Market Volatility and Global Sustainability: 1978-2007 (Whole Sample)

Dependent Variable: $GENSAV_{it}$	Cross-sectional independence		Cross-sectional dependence	
	DIF-GMM	**SYS-GMM**	**DIF-GMM-C**	**SYS-GMM-C**
$GENSAV_{i,t-1}$	0.377	0.644	0.545	0.807
	[0.073]*	[0.000]***	[0.062]*	[0.000]***
$VPRIVO_{i,t-1}$	-0.116	-0.170	-0.172	-0.234
	[0.186]	[0.022]**	[0.090]*	[0.007]***
$GR_{i,t-1}$	0.014	0.048	-0.124	0.072
	[0.928]	[0.654]	[0.489]	[0.549]
$GNIPC_{i,t-1}$	-0.065	-0.030	-0.105	-0.027
	[0.272]	[0.017]**	[0.106]	[0.056]*
AGE_{it}	-0.063	-0.474	0.030	-0.302
	[0.835]	[0.008]***	[0.925]	[0.176]
M1	0.09	0.00	0.09	0.00
M2	0.33	0.64	0.32	0.57
Sargan test	0.40	0.49	0.80	0.89
Diff-Sargan test		0.51		0.75
CSD test	0.13	0.09		
Observations	682	798	682	798

Notes: 122 countries. The financial market volatility is in terms of private credit volatility (VPRIVO), which is defined in the text. See Table 1 for more notes.

Table 6. Financial Market Volatility and Global Sustainability: 1978-2007
(Higher Energy Intensity Sample)

Dependent Variable: $GENSAV_{it}$	**Cross-sectional independence** DIF-GMM	SYS-GMM	**Cross-sectional dependence** DIF-GMM-C	SYS-GMM-C
$GENSAV_{i,t-1}$	0.201	0.493	0.435	0.609
	[0.499]	[0.000]***	[0.252]	[0.009]***
$VPRIVO_{i,t-1}$	-0.068	-0.267	-0.193	-0.279
	[0.652]	[0.073]*	[0.303]	[0.075]*
$GR_{i,t-1}$	-0.149	-0.127	-0.198	-0.048
	[0.329]	[0.414]	[0.426]	[0.820]
$GNIPC_{i,t-1}$	-0.085	-0.052	-0.116	-0.041
	[0.255]	[0.046]**	[0.193]	[0.174]
AGE_{it}	0.122	-0.772	0.286	-0.552
	[0.768]	[0.009]***	[0.516]	[0.144]
M1	0.42	0.03	0.33	0.04
M2	0.53	0.61	0.70	0.61
Sargan test	0.55	0.80	0.48	0.73
Diff-Sargan test		0.82		0.75
CSD test	0.47	0.61		
Observations	294	349	294	349

Notes: The higher energy intensity sample contains 56 countries whose averaged final energy intensities over 1978-2007 are above the median value of the averaged final energy intensities. See Table 1 and Table 6 for more notes.

Table 7. Financial Market Volatility and Global Sustainability: 1978-2007 (Lower Trade Share Sample)

Dependent Variable: $GENSAV_{it}$	Cross-sectional independence DIF-GMM	Cross-sectional independence SYS-GMM	Cross-sectional dependence DIF-GMM-C	Cross-sectional dependence SYS-GMM-C
$GENSAV_{i,t-1}$	0.469	0.635	0.601	0.648
	[0.000]***	[0.000]***	[0.004]***	[0.007]***
$VPRIVO_{i,t-1}$	-0.266	-0.150	-0.296	-0.166
	[0.078]*	[0.181]	[0.064]*	[0.171]
$GR_{i,t-1}$	0.194	0.130	0.174	0.148
	[0.192]	[0.318]	[0.280]	[0.265]
$GNIPC_{i,t-1}$	-0.020	-0.038	-0.032	-0.021
	[0.712]	[0.016]**	[0.590]	[0.185]
AGE_{it}	-0.146	-0.526	-0.111	-0.363
	[0.649]	[0.010]***	[0.724]	[0.047]**
M1	0.02	0.01	0.04	0.03
M2	0.84	0.72	0.86	0.76
Sargan test	0.75	0.51	0.74	0.33
Diff-Sargan test		0.26		0.15
CSD test	0.48	0.76		
Observations	395	461	395	461

Notes: The lower trade share sample contains 67 countries whose averaged trade shares (% of GDP) over 1978-2007 are below the median value of the averaged trade shares. See Table 1 and Table 6 for more notes.

global financial markets and the worst global recession for generations.

In summary, we find both output volatility and financial market volatility cause damaging effects on global sustainability for 122 countries, by comparing the GMM estimation methods controlling for the possibility of endogeneity bias and omitted variable bias. The negative effects of output volatility are aggravated in low income countries, higher energy intensity countries and lower trade share countries. The negative effects of financial market volatility have also been found in higher energy intensity countries and lower trade share countries. We also find evidence for cross country dependence in this context when financial market volatility is examined. The results are in general robust to the use of alternative estimation methods and data subsamples, and not due to unobserved heterogeneity, or endogeneity biases.

4.2 The Channels

In this subsection we go a step further to investigate the underlying mechanisms or channels through which volatility affects sustainable development.

Table 8 presents evidence on whether output volatility works through either investment share or financial development measure on sustainable development. When the investment share (KI) is examined, the specification tests show that the models in the first four columns are well-specified and the system GMM estimator is better than the first-differenced GMM estimator. The CSD test suggests no heterogeneous cross-sectional dependence in this context, implying that DIF-GMM and SYS-GMM estimators are consistent. Both DIF-GMM and SYS-GMM find no significant evidence for investment share KI, while VGR continues to significantly enter the models. This reveals that investment share, KI, doesn't seem to pick up any effect of output volatility on sustainable development, and therefore is not a channel for output volatility to affect sustainability.

Next we explore the possible financial development channel via private credit ratio ($PRIVO$). As suggested by the specification tests, four models are again well-specified and system GMM performs better than the first-differenced GMM. The CSD test based on the system GMM estimator

Table 8 . Channels Through Which Output Volatility Affects Global Sustainability: 1978-2007

Dependent Variable: $GENSAV_{it}$	Investment Channel				Financial Development Channel			
	DIF-GMM	SYS-GMM	DIF-GMM-C	SYS-GMM-C	DIF-GMM	SYS-GMM	DIF-GMM-C	SYS-GMM-C
$GENSAV_{i,t-1}$	0.610	0.738	0.612	0.615	0.467	0.709	0.676	0.778
	[0.000]***	[0.000]***	[0.064]*	[0.001]***	[0.003]***	[0.000]***	[0.049]**	[0.000]***
$VGR_{i,t-1}$	-0.165	-0.143	-0.206	-0.154	-0.111	-0.046	-0.193	-0.037
	[0.067]*	[0.100]*	[0.106]	[0.125]	[0.307]	[0.606]	[0.101]	[0.678]
$KI_{i,t-1}$	-0.161	-0.081	-0.192	-0.006				
	[0.542]	[0.677]	[0.647]	[0.976]				
$PRIVO_{i,t-1}$					-0.035	-0.116	-0.017	-0.125
					[0.712]	[0.037]**	[0.875]	[0.006]***
$GR_{i,t-1}$	0.002	0.094	0.060	0.162	0.011	0.180	-0.117	0.244
	[0.991]	[0.459]	[0.843]	[0.156]	[0.959]	[0.316]	[0.595]	[0.071]*
$GNIPC_{i,t-1}$	-0.059	-0.031	-0.052	-0.040	-0.075	0.014	-0.144	0.023
	[0.276]	[0.157]	[0.491]	[0.051]*	[0.337]	[0.604]	[0.163]	[0.257]
AGE_{it}	-0.137	-0.400	-0.244	-0.501	-0.031	-0.120	0.013	0.025
	[0.698]	[0.014]**	[0.641]	[0.016]**	[0.901]	[0.540]	[0.973]	[0.885]
M1	0.01	0.00	0.14	0.03	0.03	0.00	0.09	0.00
M2	0.12	0.14	0.11	0.13	0.35	0.46	0.34	0.44
Sargan test	0.53	0.71	0.38	0.77	0.32	0.19	0.41	0.41
Diff-Sargan test		0.71		0.92		0.17		0.37
CSD test	0.63	0.36			0.21	0.08		
Observations	787	910	787	910	698	811	698	811

Notes: 122 countries. The investment channel via investment share of GDP (KI) and the financial development channel via private credit ratio (PRIVO) are examined separately.

See text for the definitions of KI and PRIVO. See Table 1 for more notes.

clearly rejects the null of homogeneous cross-sectional dependence, suggesting that SYS-GMM estimator is not consistent and we shall instead rely on the SYS-GMM-C estimator. The SYS-GMM-C estimates clearly indicate that VGR is no longer significant in the model while $PRIVO$ enters the model significantly. In contrast to investment share, KI, private credit ratio, $PRIVO$, apparently picks up the effect of output volatility on sustainable development and is indeed the channel through which output volatility hampers global sustainability.

To identify the transmission channels for the negative effect of financial market volatility on global sustainability to work through, various channels have been examined, including investment share, final energy intensity, and energy consumption per capita.[17] However, there is no evidence for either final energy intensity or energy consumption per capita to enter the models significantly; for investment share, it doesn't seem to pick up any effect of financial market volatility, either. This remains an interesting area for further research.

The finding regarding a financial development channel has significant implications and sheds some light on the interaction between economic downturn and financial crisis during the 2007-2009 global financial crisis. A number of research has suggested that global financial turmoil and economic volatility have cut demand for goods and services from some developing countries, reduced trade and investment flows to and from these countries, and led to a long-run economic decline in these countries. Any associated dramatic changes in demand for goods and manufacturing could potentially lead to the wastes of natural resources, unsustainable consumption and production, and a high degree of climate risk.[18] In the process of unsustain-

[17] Data for the investment share of real GDP per capita (RGDPL) are taken from the Penn World Table 6.3 (2009). The analysis uses the logarithm of one plus the investment share of real GDP per capita (RGDPL) divided by 100. Data on final energy intensity of GDP at purchasing power parities are taken from the Global Energy Market Data (2008) of Enerdata. The analysis uses the logarithm of one plus the final energy intensity. Data for energy use (kg of oil equivalent per capita) are from the World Bank World Development Indicators Database (2009). The analysis uses the logarithm of energy use per capita.

[18] Many Economists also argue that the global economic downturn has compounded and exacerbated persistent social problems of job losses, social-economic insecurity and poverty which threaten social stability in both developed and developing countries. It has

ability caused by economic volatility, financial markets might have played a crucial role.

After the collapse of the U.S. subprime mortgage market in 2007, especially the failure of Lehman Brothers in 2008, the global economic downturn further impacted the financial system by increasing the credit risk and the levels of uncertainty. As a result, investors refused to provide funds to the banks while banks were reluctant to provide sufficient credit to creditworthy borrowers due to the loss of confidence. The credit conditions and financial markets were severely impacted with the availability of credit and insurance that facilitate manufacturing and trade being curtailed. The sharp drop in global demand for commodities and global manufacturing has been further amplified by restricted access to finance and considerable uncertainty. This further eroded the ability of economic system to maintain sound productivity and ecological processes into the future, with damaging consequences for national economy. The findings highlight the interaction between global financial markets and the wider economy as a key factor influencing the low carbon development path.

5 Summary and Conclusions

This paper investigates the issue of whether economic volatility has a damaging effect on global sustainability. It carries out a dynamic panel data study based on data for 122 countries over 1978-2007 and makes use of the genuine savings or adjusted net savings to measure the level of sustainable development. To address the issue of cross country dependence caused by global shocks, this research applies the system GMM method adjusted to allow for error cross section dependence due to Sarafidis *et al.* (2009).

This analysis finds both output volatility and financial market volatility cause damaging effects on global sustainability for the whole sample. The negative effects of output volatility are aggravated in low income countries, higher energy intensity countries and lower trade share countries, while the

hampered the efforts of developing countries towards achieving their Millennium Development Goals, and the efforts of international community towards helping deliver improved living standards for the most vulnerable people and countries.

negative effects of financial market volatility have also been found prominent in higher energy intensity countries and lower trade share countries. This analysis also identifies a financial development channel with respective to private credit ratio through which output volatility prevents sustainable development. The results are in general robust to the use of alternative estimation methods and data subsamples, and not due to unobserved heterogeneity, or endogeneity biases.

This analysis also provides evidence for cross country dependence in this context when financial market volatility is examined. This is perhaps due to the fact that financial markets are typically associated with cross-border financial linkage or financial integration; accordingly financial crisis and macroeconomic volatility in one country tend to spread around global financial markets rapidly.

The adverse effect of output volatility on sustainable development has been found exacerbated in countries that have low income per capita, higher energy intensities and lower trade shares. However, the ability to tackle volatility impacts in those countries might be constrained by weak institutions, an underdeveloped financial sector, and other political economy considerations. Empirical research continues to show that weak institutions and underdeveloped financial sector in developing countries could even amplify the adverse effects of volatility on long-run growth and sustainable development, and result in permanent setbacks and a long-run development problem relative to developed countries. Therefore it is suggested that governments of developing countries should aim for lower energy intensities, more open trade policies as well as strong institutions, good governance, and effective and equitable social and economic policies. They should also aim to liberalize financial sectors with adequate regulation and supervision and strengthen capacities to mobilize and manage financial resources and deliver public services effectively. Any efforts by governments to strengthen energy-saving development mode and macroeconomic fundamentals could help lay the foundation for a long-run sustainable development.

Internationally, it is recommended that supportive frameworks should be created for facilitating financial development, energy savings, climate change adaptation and mitigation, and low carbon economy. Dedicated resources for development should be made available for vulnerable nations and people around the world. The increased and better financial assistance will enable those countries to cope more effectively with economic volatility or crisis, and improve safety nets and basic services like health and education.

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Appendix Table 1. The Variables

Variable	Description	Source
GENSAV	Adjusted net savings, excluding particulate emission damage (% of Gross National Income). The regression uses the 3-year averages of the natural logarithm of one plus the adjusted net savings divided by 100, log(1+GENSAV/100).	World Bank World Development Indicators (WDI) (2009)
VGR	Standard deviation over 3-year interval from 1978 to 2007 of the natural logarithm of one plus the annual growth rate of GDP per capita divided by 100.	Calculated based on data from WDI (2009)
VINFL	Standard deviation over 3-year interval from 1978 to 2007 of the natural logarithm of one plus the annual inflation rate divided by 100.	Calculated based on data from WDI (2009)
VPRIVO	Standard deviation over 3-year interval from 1978 to 2007 of the natural logarithm of one plus the private credt over GDP.	Calculated based on data from the Financial Development and Structure Database (FDS) (2009)
VLLY	Standard deviation over 3-year interval from 1978 to 2007 of the natural logarithm of one plus the liquid liabilities of banks and non-bank financial intermediaries (currency plus demand and interest-bearing liabilities) over GDP.	Calculated based on data from FDS (2009)
KI	The investment share of real GDP per capita (RGDPL). The regression uses log(1+KI/100).	Penn World Table 6.3 (PWT) (2009)
PRIVO	The ratio to GDP of credit issued to private sector by banks and other financial intermediaries. The regression uses log(1+PRIVO).	FDS (2009)
GR	The annual growth rate of GDP per capita. The regression uses log(1+GR/100).	WDI (2009)
GNIPC	The gross national income per capita. The regression uses GNIPC in log.	WDI (2009)
TRADE	The trade share (% of GDP). The regression uses log(1+TRADE/100).	WDI (2009)
AGE	The age dependency ratio (dependents to working-age population). The regression uses log(1+AGE/100).	WDI (2009)

Appendix Table 2: The List of Countries in the Full Sample

Code	Country Name	Code	Country Name	Code	Country Name
AGO*	Angola	GBR	United Kingdom	NLD	Netherlands
ARG	Argentina	GHA*	Ghana	NOR	Norway
AUS	Australia	GIN*	Guinea	NPL*	Nepal
AUT	Austria	GMB*	Gambia	NZL	New Zealand
BDI*	Burundi	GNB*	Guinea-Bissau	PAK*	Pakistan
BEL	Belgium	GRC	Greece	PAN	Panama
BEN*	Benin	GTM	Guatemala	PER	Peru
BFA*	Burkina Faso	GUY	Guyana	PHL	Philippines
BGD*	Bangladesh	HKG	Hong Kong, China	PRT	Portugal
BLZ	Belize	HND*	Honduras	PRY	Paraguay
BOL	Bolivia	HTI*	Haiti	RWA*	Rwanda
BRA	Brazil	IDN*	Indonesia	SAU	Saudi Arabia
BRN	Brunei Darussalam	IND*	India	SDN*	Sudan
BTN*	Bhutan	IRL	Ireland	SEN*	Senegal
BWA	Botswana	IRN	Iran, Islamic Rep.	SGP	Singapore
CAF*	Central African Republic	ISL	Iceland	SLE*	Sierra Leone
CAN	Canada	ISR	Israel	SLV	El Salvador
CHE	Switzerland	ITA	Italy	SWE	Sweden
CHL	Chile	JAM	Jamaica	SWZ	Swaziland
CHN*	China	JOR	Jordan	SYC	Seychelles
CIV*	Cote d'Ivoire	JPN	Japan	SYR	Syrian Arab Republic
CMR*	Cameroon	KEN*	Kenya	TCD*	Chad
COG*	Congo, Rep.	KHM*	Cambodia	TGO*	Togo
COL	Colombia	KOR	Korea, Rep.	THA	Thailand
COM*	Comoros	LAO*	Lao PDR	TON	Tonga
CPV	Cape Verde	LBN	Lebanon	TTO	Trinidad and Tobago
CRI	Costa Rica	LKA	Sri Lanka	TUN	Tunisia
CYP	Cyprus	MAR	Morocco	TUR	Turkey
DMA	Dominica	MDG*	Madagascar	TZA*	Tanzania
DNK	Denmark	MDV	Maldives	UGA*	Uganda
DOM	Dominican Republic	MEX	Mexico	URY	Uruguay
DZA	Algeria	MLI*	Mali	USA	United States
ECU	Ecuador	MNG*	Mongolia	VCT	St. Vincent & Grenadines
EGY	Egypt, Arab Rep.	MOZ*	Mozambique	VEN	Venezuela, RB
ERI*	Eritrea	MRT*	Mauritania	VNM*	Vietnam
ESP	Spain	MUS	Mauritius	VUT	Vanuatu
ETH*	Ethiopia	MWI*	Malawi	ZAF	South Africa
FIN	Finland	MYS	Malaysia	ZAR*	Congo, Dem. Rep.
FJI	Fiji	NAM	Namibia	ZMB*	Zambia
FRA	France	NER*	Niger	ZWE*	Zimbabwe
GAB	Gabon	NIC*	Nicaragua		

Note: This table lists the country codes and names for 122 countries considered in the whole sample. Countries with * are made up of the low income sample in this analysis according to the World Bank Global Development Network Database (2002).