Essays on Volatility, Growth and Development: Evidence from China

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Abstract of thesis entitled:

Essays on Volatility, Growth and Development: Evidence from China

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This thesis consists of three essays, and discusses several issues about volatility, growth and development in the context of the Chinese economy.

The first essay intends to answer the following questions: "Has China's economic growth become less volatile in the reform period?" and if it is the case, "What are the sources behind the increasing macroeconomic stability?" The answer to the first question is yes. Using the quarterly data of China, this paper provides robust evidence of the existence of a structural break or regime shift in the variance of the GDP growth process (most likely in 1992 and 1993). Employing decomposition methods from different perspectives, this essay attributes the significant decline in aggregate output volatility to the following factors: the increasing stability of labor productivity growth and TFP growth at the aggregate level, the declined volatility of value-added growth at the sectoral level, the increasing stability of consumption growth and investment growth from the demand side, and the decrease in the covariances between provincial growth contributions from the regional economic perspective.

The second essay attempts to examine the underlying factors accounting for the volatility of China's economic growth. It particularly highlights the role of investment policy volatility in explaining output volatility. The results suggest

that investment policy volatility amplifies the growth volatility, whereas fiscal policy volatility has no significant effect. Government size and investment share have opposite, albeit not always significant, influences on growth volatility. The main findings are robust to the inclusion of additional controls, the substitution of initial values for the mean values of control variables, and the alternative estimation specifications of policy volatilities. It suggests that the decline in investment policy volatility accounts for a significant part of the increasing stability of China's economic growth, and that stable policies and a better institutional environment are crucial in sustaining the macroeconomic stability of China.

Unlike the conventional wisdom that growth and volatility correlate negatively across countries, the third essay finds a significant and positive growth-volatility link across Chinese provinces in the reform period. This link remains significant and positive in several robustness tests. Further analyses from disaggregate perspectives find that the output volatility is correlated with rural consumption growth and urban consumption growth negatively and positively, respectively. At the sectoral level, more volatile sectors command higher investment rate and higher value-added growth. This essay also finds that the expected volatility has positive effect on growth, while both fiscal and investment policy volatilities are significantly harmful to economic growth. However, the significances of policy volatilities vanish once expected volatility is included in the analysis. It partly confirms the analytical argument that the growth-volatility link in China is mainly driven by the positive volatility component. Moreover, a stable policy environment is vital to the economic growth of China despite a positive aggregate growth-volatility link.

摘要

本论文由三篇文章组成，主要讨论中国经济增长、波动和发展的若干相关问题。第一篇文章主要回答以下问题：中国经济增长的波动性是否在改革开放时期出现下降？如果如此，什么是中国经济增长平稳性增强的来源？本文首先使用中国季度经济数据和多种计量经济学方法回答了第一个问题。中国季度GDP 增长的方差存在一个显著的结构性断点或状态转变，在统计学意义上，这一变化上发生在 1992-1993 年。随后，本研究使用多种视角的波动分解方法将经济增长波动的显著降低归结为以下几个因素：劳动生产率和全要素生产率的波动性降低（总体生产视角）、各行业增加值增长的波动性降低（行业生产视角）、消费和投资增长的波动性降低（总需求视角）和省际经济增长贡献率之间协方差的减少（区域经济视角）。第二篇文章主要讨论哪些因素可以解释中国经济增长波动，并重点强调了投资政策波动的作用。本文分析显示投资政策波动显著扩大了经济增长波动性，而财政政策波动则对经济增长波动没有显著作用，政府规模和投资率对波动产生相反的作用。上述结论在一些稳健性检验中依然成立，例如加入其它控制变量、使用控制变量的初始值代替均值和使用其它方法估算政策波动等。本文结论表明，投资政策波动的降低显著地增强了中国经济增长的稳定性，稳定的政策和制度环境对保持中国宏观经济稳定十分重要。不同于跨国实证研究中的传统结论——增长与波动负相关，第三篇文章发现了在改革开放时期中国各省之间的增长与波动存在显著的正向关系。这一关系在一些稳健性检验中依然保持正向且显著。进一步的分解视角分析表明产出波动与农村居民消费增长和城镇居民消费增长分别呈负向和正向关系。在跨省跨行业层面，波动性强的行业对应更高的投资率和更高的增加值增长率。本文还发现预期波动对经济增长存在显著正向影响，而财政政策波动和投资政策波动均显著地阻碍经济增长，但一旦预期波动也纳入回归分析，政策波动的显著性消失。这一定程度上肯定了本文分析性框架的结论，即中国的增长-波动关系主要被正向波动因素驱动。尽管总体的增长-波动关系为正，但本文分析表明稳定的政策环境对经济增长是十分关键的。

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Abstract

This essay intends to answer the following questions: "Has China's economic growth become less volatile in the reform period?" and if it is the case, "What are the sources behind the increasing stability of the Chinese economy?" The answer to the first question is yes. Using the quarterly data of China, this paper provides robust evidence of the existence of a structural break or regime shift (most likely in 1992 and 1993) in the variance of the GDP growth process. The result is robust to the alternative quarterly GDP growth measures and approaches of structural break or regime switching detection. Employing decomposition methods from different perspectives, this essay attributes the significant decline in aggregate output volatility to the following factors: the increasing stability of labor productivity growth and TFP growth at the aggregate level, the declined volatility of value-added growth at the sectoral level, the increasing stability of consumption growth and investment growth from the demand side, and the decrease in the covariances between provincial growth contributions from the regional economic perspective.

JEL: E32; O40; O53; R11

Keywords: Chinese Economy; Volatility Decomposition; Business Cycles; Structural Break; Markov Switching

1 Introduction

Over the last three decades (1978–2009), the average rate of China's GDP growth is 9.85%, while its standard deviation is 2.73% (maximum of 15.18% in 1984 and minimum of 3.84% in 1990). The outstanding performance of China's economic growth in the reform period has been extensively investigated by Young (2003), Prasad and Rajan (2006), Bosworth and Collins (2008), Hsieh and Klenow (2009), and Brandt and Zhu (2010).[1] However, mainly due to data limitations,[2] studies on business cycles and fluctuations of the Chinese economy are limited, although the cyclical pattern in China's economic growth is prominent.

Apart from the long-term high growth, the volatility of GDP growth during the reform period is smaller than that in the pre-reform period.[3] Chow (1993) argues that the key driving force of the economic growth before 1978 is investment, which is affected significantly by the policies of the central government. Frequent political struggles and political campaigns have resulted in high level of policy uncertainties, thus leading to high investment and growth volatility (Chow, 1993; Hsu and Zhao, 2009).[4] Nevertheless, even in the reform period, a substantial decline in the volatility of economic growth is

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[1] Young (2003), Bosworth and Collins (2008), Hsieh and Klenow (2009), and Brandt and Zhu (2010) investigate the driving forces of China's economic growth using different growth accounting methods. Prasad and Rajan (2006) discuss the paradigm and lessons of China's economic performance during the reform period.

[2] The official estimates of quarterly data on GDP have only been available since the first quarter of 1992.

[3] In the pre-reform period (1952–1977), the standard deviation of GDP growth is 10.48%, whereas that in the reform period (1978–2009) is 2.73%.

[4] Chow (1993) argues that in the pre-reform period, there is no technical change in China, and the economic growth is triggered mostly by investment. The aggregate economy experienced remarkable losses during the periods of the Great Leap Forward and Cultural Revolution. The standard deviations of investment growth (i.e., growth of gross fixed capital formation as a proxy) are 26.64% and 7.39% in the pre-reform period and reform period, respectively. Hsu and Zhao (2009) document the noticeable moderation of volatility after 1978, but argue that the total factor productivity (TFP) shocks and the government expenditure shocks account for the decline in the volatility of economic growth after 1978.

evident. For simplicity of comparison, we divide the reform era into two sub-periods using 1992 as the break year, when China eventually confirmed its development strategy of incremental reform toward the market economy after the south tour speeches of Deng Xiaoping. The mean growth rates for the two sub-periods (1978-1992 and 1993-2009) are only slightly different from each other, whereas the standard deviation of GDP growth in the first sub-period (3.50%) is 1.85 times as large as that in the second sub-period (1.89%).[5] By conducting Levene's robust test for the equality of variances, we can reject the equality of the standard deviation of GDP growth for the two sub-periods at the 1% significance level. From this simple two sub-period comparison, the significant decline in the volatility of GDP growth is suggestive.

This phenomenon of decreasing growth volatility in the second half of the reform period has been documented by Michael (2004), Gao (2007) and He, Chong and Shi (2009), although they simply describe the phenomenon as a stylized fact of the Chinese economy. Several studies have proposed underlying explanations for the cyclical pattern of in the economic growth of China; however, they do not investigate the sources of the decline in the volatility of economic growth. For instance, Brandt and Zhu (2000; 2001) propose an analytical framework and a positive general equilibrium model to attribute China's cyclical economic growth to decentralization, the commitment of the government to state-owned enterprises (SOEs), and imperfect credit control. The tensions between the central government and local governments as well as the macro control policies and implementations are also considered potential

[5] The average GDP growth rates are 9.59% and 10.08% for the sub-periods 1978–1992 and 1993–2009, respectively. Using both T-tests with equal variance and unequal variance, we cannot reject the hypothesis of equal mean of the two sub-periods. On the contrary, by conducting Levene's robust test for the equality of variances, we can reject the equality of standard deviation of the two sub-periods at the 1% significance level.

driving forces of the Chinese business cycles as well (Naughton, 1995b; Yu, 1997).

In this essay, we intend to answer the following questions: "Has the economic growth of China become less volatile in the reform period?" and if this is the case, "What are the sources of the increasing stability of the Chinese economy?" Using the quarterly economic data of China, we identify the instability in the country's economic growth and further provide robust evidence of the existence of a structural break or regime shift in the variance of GDP growth process. Subsequently, we employ decomposition methods from different perspectives to investigate the sources of the significant decline in the volatility of GDP growth. The main results are summarized below.

First, we construct the quarterly data series on real GDP growth for the reform period (1978 Q1 to 2009 Q4), after which we examine the stability of quarterly GDP growth and find a one-time structural break in the variance of the GDP growth process. Further analyses indicate that the structural break or regime switching is likely to occur in the early 1990s and late 1992 or early 1993, which is considered to be the break date. The findings are robust to the alternative measures of the quarterly GDP growth, including four-quarter growth, Hodrick-Prescott (HP) filtered GDP, and Band-Pass (BP) filtered GDP. They are also robust to the alternative approaches of structural change and regime switching, including Nyblom-Hansen's L test, SupF tests for structural break, and Markov Switching autoregressive (AR) models, among others. We conclude that there is a one-time structural break or regime switching from a higher-variance state to a lower-variance state in the quarterlry GDP growth of China, and that the break date is most likely in the years 1992 and 1993.

Furthermore, we employ several decomposition approaches from different perspectives to examine the sources of the increasing stability of the economic growth of China. According to the detected timing of structural break in the variance of GDP growth, the reform period is divided into two sub-periods, namely, 1978-1992 and 1993-2008. Owing to limited data availability, only the annual data are available and employed. We compare the decomposition results for the two sub-periods and illustrate the patterns of output volatility and its decomposed components using rolling results.

From the production perspective, the aggregate volatility is decomposed into the variances of employment growth and labor productivity growth and their covariances. Subsequently, the growth accounting analysis attributes volatility to the contributions from variances of factor input growth and covariances between them. The results suggest that both employment growth and labor productivity growth become stable, and the variance of the latter dominates the decline in volatility of economic growth in terms of magnitude. Furthermore, lower volatile total factor productivity (TFP) growth and the declining covariance between TFP and capital input growth account for most of the decline in output volatility. This is consistent with the argument of He, Chong and Shi (2009), which states that TFP best explains the Chinese business cycle.

At the sectoral level, we decompose the aggregate volatility into the contributions from the variances of sectoral value-added growth and covariances between them. The value-added growth rates of the three main economic sectors become more stable. The decline in aggregate volatility reflects the direct contributions of the decreased sectoral variances, which is dominated by the secondary sector in terms of magnitude. Even in considering a 9 sub-sector classification, similar results emerge. The decline in aggregate volatility can be mainly traced from idiosyncratic shocks to individual sectors rather than common shocks across sectors. Furthermore, sectoral labor productivity decomposition indicates that the variances of sectoral labor productivity and their covariances account for most of the aggregate volatility decline, which is consistent with the previous findings about the dominant role of productivity.

From the demand perspective, aggregate volatility is decomposed into the contributions from the variances of final demand growths and their covariances. Most of the aggregate volatility decline is attributed to the increasing stability of growth contributions of all demand components, which is dominated by consumption and investment. Interestingly, all pairwise correlations between net exports and each of other three components show an increasing trend, while the pairwise correlations between any two local demands experience a decline or at least a stable pattern after the early 1990s. The different trends among the correlations suggest that with the increasing integration with the global economy, trade (i.e., net export) is becoming more and more associated with local final demands.

The last perspective of volatility decomposition concerns the regional economy in China. Most provinces have experienced a significant drop in the volatility of both economic growth and growth contribution after 1992. However, the decline in aggregate output volatility reflects the decrease of covariances between provincial growth contributions. This result is associated with the prevailing effects of common factors across provinces and the increasing economic integration and co-movements (Xu, 2002; Xu and Voon, 2003). Moreover, we divide 31 provinces into 3 groups (i.e., eastern, central and western group) and find that both the within- and between-group covariances account for the significant parts of the aggregate volatility decline. Furthermore, all correlations within and between groups show a slight increase after 1992, suggesting that the drastic drop in covariances mainly reflects the increasing stability of provincial economic growth rather than the change of their pairwise correlations.

This study contributes to the literature on the Chinese economy in several aspects. First, to the best of our knowledge, this essay is the first to provide a rigorous analysis on the prominent phenomenon of drastic decline in output volatility of China, with the aim of detecting the structural break in growth volatility and examining the sources of volatility decline using several decomposition methods. Second, we provide a comprehensive view of volatility decomposition from the perspectives of production, demand, and the regional economy. In particular, the volatility decomposition from the regional economic perspective is an initiative investigation into this issue. Third, the result of this study, that a structural break exists in the variance of China's GDP growth, has important implications for future theoretical and empirical analysis about the Chinese economy.

The rest of the essay is organized as follows. Section 2 reviews the literature related to Chinese business cycle and output volatility. Section 3 introduces the data construction of quarterly GDP data and the adjustment of annual economic data; it also provides some stylized facts of the economic growth of China. Sections 4 and 5 analyze the structural break and regime switching in the variance of economic growth, respectively. Sections 6, 7, and 8 employ different volatility decomposition methods to investigate the sources of decreased volatility, from the production, demand, and regional economic perspectives, respectively. Finally, Section 9 concludes this essay.

2 Literature Review

The cyclical pattern of China's economic growth after 1978 has been documented beginning in the early 1990s, such as in the works of Yusuf (1994) and Naughton (1995b). Limited studies on Chinese business cycles mostly focus on four kinds of issues, namely, (1) stylized facts and characteristics of Chinese business cycles, (2) the co-movement of output and inflation, (3) economic synchronization within China, and (4) the explanations for China's cyclical economic growth pattern.

The cyclical "stop-go" pattern of economic growth is considered as the major feature of the Chinese business cycle (Yusuf, 1994; Naughton, 1995a; b). Despite the differences in their methods of identifying a cycle, Oppers (1997), Yu (1997), and Zhang and Wan (2005) state that China has experienced several business cycles since 1978. Further studies on the features of Chinese business cycle suggest that the presence of an asymmetric business cycle is significant in China. For instance, using an asymmetric condition volatility model (ARMA-EGARCH), Ho and Tsui (2004) find that the volatility of China's quarterly GDP growth is asymmetric, because the negative shocks result in greater future volatilities than positive shocks. As a result, the contractionary policies against the overheating of the economy are likely to induce higher future volatility. Moreover, in order to investigate the business cycles in China since the 1990s, Wang, Gao, and McNown (2009) compute the composite coincident index[6] and find significant asymmetries over the last two

[6] The composite coincident index is based on the Stock-Watson model and the Dynamic Markov Switching Factor (DMSF) model.

decades. This presents a pattern of longer duration and smaller amplitude in the expansion state. In addition, they also find shorter duration and larger amplitude in the contraction state. The asymmetries in the Chinese business cycle suggest that more flexible and counter-cyclical monetary and fiscal policies are more suggestive rather than rigidly controlled policies (Ho and Tsui, 2004).

Another prominent feature of the Chinese business cycle is the co-movement of output and inflation in the reform period. In fact, some argue that co-movement has been very significant after 1978 (Yusuf, 1994; Oppers, 1997). Brandt and Zhu (2000; 2001) provide a positive general equilibrium model to explain the co-movement as well as the cyclical pattern of economic growth. This shall be discussed later in this essay. A special phenomenon about such co-movement is discussed by Gong and Lin (2008), in which they develop a model to explain the "deflationary expansion" puzzle in the late 1990s and early 2000s in China. They argue that the high economic growth with deflation is driven by an overshooting in investment and a steady state at a high growth rate.[7] Furthermore, using an augmented EGARCH model, Narayan, Narayan, and Smyth (2009) examine several hypotheses about the link between inflation and output growth for China. They report the following results: increased inflation uncertainty lowers average inflation, inflation volatility hampers economic growth, and higher output volatility increases economic growth.

The regional business cycles and the synchronization of provincial economic growth have been investigated by several studies. Tang (1998) uses data on the

[7] Gong and Lin (2008) suggest that the steady state of high growth rate can be explained by the institutional environment of China. High growth of investment results in high economic growth, fast capital accumulation, and aggregate demand that require more labor forces to work in urban areas. The dual track of the Chinese economy makes labor transfer and labor absorption possible. Furthermore, the state-owned banks provide sufficient credit to finance the high growth of investment even if the investment efficiency is debatable.

correlation of business cycles in 28 Chinese provinces to examine the degree of economic integration. He finds that the shocks to provinces are not uniformly correlated; hence, it is not appropriate to treat Chinese provinces as a united homogenous economy. Poncet and Barthelemy (2008) study the factors affecting the economic integration of China, using monthly output data of 30 Chinese provinces for the years 1991–2004. They find that trade integration, fiscal policy coordination, production structure, and international trade dissimilarity are associated with the business cycle synchronization within China.[8] Furthermore, the provincial sectoral value-added growth for the years 1991-1998 is decomposed into common nation effect, sector-specific effects, and province-specific effects by Xu (2002) and Xu and Voon (2003). Significant co-movements (national effects) dominate in the output growth, although the economic integration of Chinese provinces is still incomplete. Moreover, several results of particular sectoral and provincial growth are concluded.[9] A recent study employs annual data and investigates the business cycle and inflation synchronization in China (Gerlach-Kristen, 2009). There has been a synchronization of both economic growth and inflation cycles within China. The synchronization of economic growth started from the mid-1980s, while that of inflation started from the 1960s.

Given the noticeable features of the Chinese business cycles, several studies have devoted their efforts to discuss the underlying explanations for the cyclical pattern of the Chinese economy. Three supplementary explanations have been reported.

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[8] Poncet and Barthelemy (2008) state that trade integration and fiscal policy coordination are positively associated with synchronization, whereas production structure divergence and international trade dissimilarity are negatively linked with the co-movements of the economic growth of Chinese provinces.

[9] Xu (2002) and Xu and Voon (2003) also find that the industrial sector is likely to be pro-cyclical, whereas the primary and service sectors tend to be counter-cyclical. The service sectors can serve as buffers to economic volatility. Coastal provinces are mostly pro-cyclical, whereas central provinces follow the national cycle, but less closer than do the coastal provinces.

The first one focuses on the reform of SOEs (Lin, Cai and Li, 1998; Lin and Tan, 1999). Moreover, the first explanation argues that the cyclical pattern of economic growth and inflation before the early 1990s results from the shift from a flexible credit plan to administrative credit plan, which is due to the government's imperfect control of credit allocation, its commitment to SOEs as well as decentralization (Brandt and Zhu, 2000; 2001). Before the early 1990s, SOEs took the responsibility of production and social stability (Bai et al., 2000; Bai, Lu and Tao, 2006). Owing to the state-imposed policy burdens,[10] SOEs were subject to soft budget constraints, since the states were accountable for those SOEs with poor operation and financial performances (Lin, Cai and Li, 1998; Lin and Tan, 1999). The government supports employment and investment growth in relatively inefficient SOEs with transfers in the form of cheap credits from state-owned banks and money creation. As a result of decentralization, the state-owned banks prefer to divert credit resources to more productive non-SOEs under a flexible indicative credit plan, resulting in a higher economic growth. However, due to the commitment on employment growth in SOEs, more transfers are needed for the government. Consequently, aside from the limited fiscal subsidies, money creation is the first choice in financing the transfers to SOEs; hence, inflation rises along with economic growth. Eventually, the increasing inflation resulting from unsustainable money creation induces the Chinese government to shift the indicative credit plan to administrative credit plan. Therefore, the economic growth slows down due to the administrative credit and money creation and inflation are reduced. A new round of growth and inflation begins as the indicative credit plan is adopted again. As long as SOEs are imposed with policy burdens and are

[10] Lin and Tan (1999) state that the state-imposed policy burdens mainly include welfare costs, redundant workers, and the persistence of price distortions.

subject to soft budget constraints, the Chinese government has to maintain its commitment on employment and investment growth of SOEs, and hence volatile business cycles persist (Brandt and Zhu, 2000; 2001).

The second explanation is associated with the implementations of macro-control policies (Yu, 1997; Michael, 2004). China is a typical transitional economy, which has experienced a shift from a centralized planned economy to a market economy, accompanied by tensions between the central and local governments about investment over the last three decades. Once the rigid restrictions on credit and investment are lifted, this results in the local governments experiencing "investment hunger" (Yusuf, 1994; Naughton, 1995a). Even recently, the tendency of over-investment remains despite the improvement of investment efficiencies (Qin and Song, 2009). Such investment hunger and extensive growth can continue until the central government decides to impose strict macro-control policies to control the increasing threat of inflation and economic overheating (Yu, 1997). It is observed that a series of strong macro-control policies were implemented just after each local peak of economic growth. The investment hunger of local governments and the implementation of macro-control policies of the central government may account for a significant part of China's cyclical economic growth.

The third category of studies employs different accounting methods to gauge the dominant factors of the Chinese business cycle. Gao (2007), Hsu and Zhao (2009), and He, Chong, and Shi (2009) follow the business cycle accounting method of Chari, Kehoe, and McGrattan (2007) in investigating the sources of the Chinese economy's volatility. They reach the similar conclusion that TFP best explains the fluctuations of aggregate economic variables over the last three decades.[11] Another study uses a structural vector autoregressive (VAR) model from an AD-AS perspective to investigate the Chinese business cycles over the period of 1985-2000. Zhang and Wan (2005) find that demand shocks have stronger effects on output and inflation than supply shocks, although both shocks show a declining trend.

Finally, this study is associated with recent studies on the "Great Moderation" of US and other developed economies. The new stylized fact of the increasing stability of US economy has been attributed to several underlying explanations, such as structural change, good luck of smaller shocks, financial innovations as well as improved monetary policy and inventory management (Stock and Watson, 2002). Among these studies, two papers are mostly linked with this study. The first paper provides abundant evidence of the presence of a structural break in the variance of US economic growth in the first quarter of 1984 and further decomposes the aggregate volatility into contributions from different categories of goods production (McConnell and Perez-Quiros, 2000). The second one examines the decline in the volatility of US GDP growth from a production perspective (Stiroh, 2009). Stiroh (2009) employs a decomposition method at both the aggregate and industry levels to explore the sources of the increasing stability of the US economy.

According to the literature review on output volatility and Chinese business cycles, the phenomenon of our interest in the drastic decline in the volatility of GDP growth after the early 1990s has only been documented as a stylizes fact by Michael (2004), Gao (2007), and He, Chong, and Shi (2009). Studies on the drastic changes of Chinese output volatility and further investigations on the

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[11] Gao (2007) uses a closed economy model, whereas Hsu and Zhao (2009) and He, Chong, and Shi (2009) employ an open economy model to conduct the business cycle accounting exercise. He, Chong, and Shi (2009) also find that investment and foreign debt wedges play important roles in investment and consumption. In addition, the labor wedge affects the movement of the labor forces.

sources of this decline are scarce. In this essay, we use quarterly GDP data to examine rigorously whether the GDP growth of China has become more stable in the second half of the reform period. This study also incorporates several decomposition methods to investigate the sources of decline.

3 Data and Stylized Fact

3.1 Quarterly Data

A favorable measure of economic growth is the quarterly GDP growth, which can capture more underlying information about the dynamics of economic growth using higher frequency data. Unfortunately, the national quarterly economic data of China are limited and only several aggregate variables have been made available in recent years. China's National Bureau of Statistics (NBS) reports quarterly data on nominal values and real growth rate (year-over-year) of the cumulated quarterly GDP for the years after 1992 as well as those of cumulated quarterly value-added for the three main economic sectors.[12] Given the cumulated data, we can obtain the quarterly nominal GDP and real GDP growth rate through data transformation.

To construct the quarterly series for the period before 1992, we use the values of the quarterly real GDP growth for the years 1979 to 1992 from Rajaguru and Abeysinghe (2004). They follow the approach developed by Chow and Lin (1971) to find several GDP-related quarterly series and to choose a reasonable prediction equation by running a regression of the annual GDP on a number of related annual series. Aside from the quarterly data after 1992 from NBS, we also use the data on quarterly real GDP growth for the period of 1979–2009 and the quarterly nominal GDP values after 1992. The next step is to

[12] The three main economic sectors refer to the primary, secondary, and the tertiary sectors.

construct quarterly real GDP series using 2002 as the base year. Year 2002 is chosen because the real and nominal GDP growth rates in 2002 are roughly the same for both the annual and quarterly series.

Finally, quarterly real GDP should be seasonally adjusted. We employ the widely used approach of X12-ARIMA, which was developed by the U.S. Census Bureau (Monsell, 2007), to perform the seasonal adjustment. Given the significant differences in holidays, trading days, and so on between China and US, we only incorporate the length of the quarter factor into the ARIMA regression, whereas the transformation method (taking logarithm or not) and the ARIMA model used are selected automatically by the X12-ARIMA. The quarterly real GDP data after the seasonal adjustment are then used to derive the seasonally adjusted quarterly real GDP growth.

Generally, the quarterly real GDP growth is directly reported in two estimates, a year-over-year rate and an annualized quarter-over-quarter rate. The year-over-year estimate is the quarterly GDP growth compared with the same quarter of the previous year, and employed as the Four-Quarter growth rate by Stock and Watson (2005). In this essay, the year-over-year estimate is denoted as "FQ", whereas the quarter-over-quarter estimate, referring to the quarterly GDP growth at annual rate compared with the previous quarter, is denoted as "PQA."

The two alternative measures of the GDP growth are the log GDP series[13] adjusted by Hodrick-Prescott (HP) filter (Hodrick and Prescott, 1997) and the Band-Pass (BP) filter (Baxter and King, 1999); both are conventional and widely accepted de-trending methods. For the HP-filtered series, the smoothing

[13] Prior to using the Hodrick-Prescott filter and Band-Pass filter, we first obtain the log GDP series by taking natural logarithm of the quarterly GDP. Afterwards the log GDP series is filtered using the two filters individually.

parameter is set to 1600 (Ravn and Uhlig, 2002) because the real GDP in this study is the quarterly data. For the BP-filtered series, the cyclical component of fluctuation is identified as that retained with period between 6 and 32 quarters following the conventional settings (Stock and Watson, 2005; Galí and Gambetti, 2009). The leading lag length is set to 12, in accordance with the suggestion of Baxter and King (1999).

Following the similar data treatment procedure applied to the data of the GDP series, we can obtain the quarterly real value-added and its growth for the three main economic sectors. Subsequently, the real value-added data are seasonally adjusted, after which we derive the four estimates of seasonally adjusted real value-added growth, namely, the year-over-year estimate (FQ), the annualized quarter-over-quarter estimate (PQA), HP-filtered estimate, and BP-filtered estimate (BP).

Figures 1 and 2 show the seasonally adjusted quarterly series of the real GDP and the real GDP growth. Figure 2 shows that the basic patterns of the quarterly GDP growth are still similar regardless of the estimate used. Certainly, due to the definition of annualized quarter-over-quarter growth, a more volatile dynamics is shown compared with the other three estimates.

[FIGURE 1 HERE]

[FIGURE 2 HERE]

After obtaining the quarterly real GDP growth and nominal GDP, we can calculate the implicit GDP deflator using the equation below. Other quarterly price indexes are obtained by simply calculating the monthly average for every quarter, including the Consumer Price Index (CPI) and the Retail Price Index (RPI). It is noteworthy that CPI data are only available for the months after

1990, whereas RPI data are available for the months after 1983. As a result, the CPI series for the period starting from 1990 Q1 and the RPI series for the period starting from 1983 Q1 are derived as follows:

$$Deflator_t = \frac{NGDP_t}{NGDP_{t-1} \cdot GDPG_t} \qquad (1)$$

where $Deflator_t$, $NGDP_t$, and $GDPG_t$ represent GDP deflator, nominal GDP and real GDP growth at time t, respectively.

Hereafter, without explicit statement, the seasonally adjusted real GDP series and the year-over-year quarterly GDP growth (FQ series) are employed for further analysis. Moreover, the PQA quarterly GDP growth and the HP-filtered and BP-filtered GDP series are used for the robustness tests.

3.2 Annual Data

To further investigate the sources of change of the output volatility, we utilize annual data so that more information can be incorporated into the analysis. Certainly, annual data are less frequent than quarterly data, but using them is the best way to uncover the sources of change of the output volatility.[14] The annual data employed in the current study include national data and provincial data. National economic data cover GDP, GDP by expenditure approach, GDP by income approach, labor, capital stock, value-added, and the employment of the three main economic sectors over the years 1978–2008. The provincial economic data include the provincial GDP for 31 provinces over the years 1978–2008. The sources and adjustment rules of the annual data are briefly introduced below.

[14] The long series of quarterly data (reform era) are only available for GDP and for some price indexes. The GDP components by expenditure approach, employment, investment, and other important variables do not have long series of quarterly data.

3.2.1 GDP and Value-Added

The nominal values and real growth rates of GDP used in this essay come from the *Chinese Statistical Yearbook 2009* (*CSY 2009*), in which the figures after 1993 are adjusted significantly according to the results of the 2004 Economic Census. The nominal values and real growth rates of value-added of the three main economic sectors are also obtained from the *CSY 2009*.

Data on GDP by expenditure approach come from the *Data of Gross Domestic Product of China (1952–2004)* (*GDP 1952–2004*) and *CSY 2009*. The nominal values and real growth rates of all the expenditure components of GDP for the years 1978–2004 are from *GDP 1952–2004*. Only the nominal values of all expenditure components for the years 2005–2008 are available in *CSY 2009*. Hence, the nominal values of each expenditure component for 2005–2008 are deflated by the corresponding price index or deflator to derive the real growth rates.[15]

Data on GDP by income approach are only available at the provincial level rather than at the national level for the years 1978–2008. As a result, we consider the sum of all provincial values as the national value. The data on GDP by income approach have the same sources with those data on GDP by expenditure approach.

Data on provincial GDP are obtained from *Comprehensive Statistical Data and Materials on 60 Years of New China* (*60 Years*), *1952–2004 GDP*, and the corresponding issues of *CSY*.

[15] The total consumption, household consumption, and government consumption are deflated by the Consumer Price Index (CPI). The gross capital formation, gross fixed capital formation, and change of inventory are deflated by the Price Index of Investment in Fixed Assets (PIIFA). The net export is deflated by an implicit GDP deflator, as shown in Equation 1.

3.2.2 Employment

Total employment and sectoral employment should be treated carefully. First, "employment," as used in this study, refers to the employment of persons aged 16 and above who are engaged in economic activities and receive payment or earn business income. The total employment is the sum of employment of the three main economic sectors. Two kinds of employment data coexist, namely, data from population census and data from report-form statistical system. Most of statistical publications provide revised report-form employment data. However, the employment data for the years after 1989 are revised according to the 1990 and 2000 population census, whereas data for the years before 1990 are not. As a result, a statistical break in 1990 has emerged in the national employment data (Holz, 2009a). For instance, according to *CSY*, the total employment of China in 1990 shows an annual growth of 17.0%, which is unreasonable and unreliable compared with the rates of 1.8% and 1.1% in 1989 and 1991, respectively. Furthermore, the statistical break in 1990 is also found in the provincial employment data of Jiangsu, Shandong, Hubei, and Qinghai.

Total employment data for the years 1990–2008 are employed in this essay because they have been revised by the NBS using the employment values in the 1990 and 2000 population census as adjustment anchors (Holz, 2009a). To construct consistent and comparable data on employment, we adjust employment data for the years 1978–1989, following the similar approach to data adjustment of post-1990 employment. We use the values of total employment in the 1982 and 1990 population census as adjustment anchors of the total employment for the years 1978–1989. Total employment values for the years 1983–1989 are derived by covering the same proportion of the distance between the 1982 and 1990 census values as the report-form values in

CSY do. Furthermore, the values for the years 1978–1981 can be obtained by applying the growth rates of report-form data in CSY to the total employment value of 1982 population census. The details of adjustment rules are similar to the efforts of Holz (2009a).[16]

Here we can obtain consistent and comparable data on total employment for the years 1978-2008. Subsequently, to derive the employment data of the three main economic sectors, we apply the original sectoral employment shares to the adjusted total employment values for the years 1978–2008. Although this approach is not perfect, it is the best available method that can be used at this point.

3.2.3 Capital

Following Chow (1993), Young (2003), and Bai, Hsieh and Qian (2006), the capital stock of China is constructed using Perpetual Inventory Method (PIM). Here, the capital stock can be estimated using the hypothesis of a geometric diminishing relative efficiency:

$$K_t = K_{t-1}(1-\delta_t) + I_t, \tag{2}$$

where K_t and I_t are the capital stock and investment at constant price at time t, respectively, and δ_t is the depreciation rate of the capital stock.

[16] See Appendix 13 of Holz (2009). The adjustment strategies can be summarized as follows. First, the report form total employment values for the years 1978 to 1990 are turned into mid-year values. Mid-year values can be simply obtained by taking arithmetic average of the two relevant year-end report form values. Second, in each year, the proportion of the distance between 1982 and 1990 report form values in *60 Years* covered is applied to the distance between the 1982 and 1990 population census employment values, and then added to the 1982 population census values. Third, the total employment values for the years 1978–1981 are obtained by applying the growth rates of the report form values in 60 Years to the 1982 population employment values. At last, the adjusted mid-year values for the years 1978–1989 are then turned into year-end values.

To construct the capital stock series, four variables are necessary, namely, (1) the investment at current price, (2) deflator for investment, (3) the depreciation rate of capital stock, and (4) the capital stock in the base year. First, we choose gross fixed capital formation (GFCF) as the proxy of investment rather than the gross capital formation, because the change of inventory in China is often calculated and considered as a residual term (Young, 2003).

As Xu (2004) states, the GFCF at constant price is deflated using the price index of fixed asset investment (PIFAI). However, PIFAI data are only available in the years after 1990. As a result, given the available data on GFCF at current price and the index of GFCF, the PIFAI data for the years before 1991 are constructed using implicit deflator for fixed capital formation, following Young (2003) and Zhang (2008). Hence, values of the constructed investment deflator series before 1991 are the implicit deflators for GFCF while values after 1990 are those for PIFAI.

Most studies have assumed a fixed depreciation rate for the capital goods in China, despite the fact that the values are different. Perkins (1988) and Young (2003) use depreciation rates of 5% and 6%, whereas Bai, Hsieh, and Qian (2006) assume different depreciation rates for structures and machineries as well as calculate an average depreciation rate. Zhang (2008) calculates an average constant depreciation rate of 9.6% by assuming different durations of investment lives on construction, equipment purchase, and others.[17] In our

[17] First, he assumes 4% as the rate of the residual value from the total value of capital goods, which means that in the end life of capital goods, the relative efficiency is 4%. Subsequently, the different durations of investment lives on construction, equipment purchase, and others are assumed to be 45, 20 and 25 years, respectively. Hence, the depreciation rates of these three components of capital goods are 6.9%, 14.9% and 12.1%, respectively. Third, the average relative shares of the three components of fixed capital formation are 63%, 29% and 8%, respectively, over the period of 1952-2004. Therefore, the rate of depreciation is 9.6%, which is identical for all provinces and all years.

study, the base value of depreciation rate is set to 9%, and other alternative values, such as 6%, 8% and 10%, are used to conduct sensitivity tests.

Finally, due to the limited data, the base year of capital stock construction is set at 1952. The methods of estimating the capital stock of base year greatly vary among different studies. Chow (1993) uses his unique estimation on the capital goods of China in 1952, i.e., 175 billion RMB at the 1952 price. In contrast, Young (2003) and Zhang (2008) utilize another approach, by which the capital stock of the base year is calculated by dividing the value of fixed asset investment in 1952 by the sum of depreciation rate and average real investment growth rate in the first five years. Significantly, because the focus of this study is the period after 1978, which is 26 years after the base year, the estimation of initial capital stock has a slight influence on the capital stock for the years after 1978. Thus, any reasonable assumption of the initial capital stock estimation is acceptable (Young, 2003). Following the method of Young (2003), in order to calculate the initial capital stock, we divide the values of GFCF by the sum of depreciation rate (with 9% as the base value) and the average real growth rate of GFCF.

3.3 Stylized Facts

Over the last three decades, China has achieved outstanding economic performance, although this is also accompanied by remarkable volatilities. The average real GDP growth rate over the years 1978–2009 is 9.85%, while the standard deviation is 2.73%. In this essay, standard deviation is used as a measure of volatility. Figure 3 provides the rolling standard deviation of annual real GDP growth since 1978, which is accompanied by real GDP growth. Here, a window of 5 years is used; thus, the volatility of year t is the standard deviation of economic growth over the year t-4 to t. The volatility of

GDP growth declines over time, especially after the early 1990s, from about 5% in the early 1980s and early 1990s to less than 1% in the early 2000s, except that there is a mild increase recently caused by the recent global financial crisis. However, the declining trend is not smooth, and a dramatic drop has occurred around the early 1990s.

[FIGURE 3 HERE]

Similar to the analysis of annual series, in this section, a rolling standard deviation of quarterly GDP growth is calculated with a rolling window of 20 quarters (Figure 4). The volatility reported for quarter t is the standard deviation of quarterly GDP growth over the period t-19 to t. Taking four-quarter GDP growth (FQ) for example, the first available quarter for GDP growth is 1979 Q1, which makes 1983 Q4 as the first reported quarter for the volatility of quarterly GDP growth. Figure 4 presents a same pattern with Figure 3. Both figures show a declining volatility over the last three decades as well as a sharp drop in early 1990s. The rolling standard deviation of GDP growth for PQA series, HP-filtered series, and BP-filtered series are illustrated in Figures A1, A2 and A3, respectively, all of which show similar patterns to that shown in Figure 4.

[FIGURE 4 HERE]

4 Structural Break in GDP Growth

Given the visually drastic drop in the output growth volatility in the early 1990s, we analyze more rigorously whether and when the volatility of GDP growth experienced a structural change in this section, using several econometric approaches. The main estimate of GDP growth used is the four-quarter GDP growth (FQ series), while other estimates are subject to robustness tests.

4.1 Simple Regression

At the beginning, we employ a simple regression model to illustrate the possible existence of volatility instability. A constant and a time trend are fit to GDP growth in a simple regression. The results show a statistically insignificant coefficient on the trend term. This insignificance of time trend is robust to the use of the first difference of GDP growth as the independent variable and to the inclusion of the lag terms of GDP growth in the regression (see the first 4 columns of Table 1). These results roughly indicate that no time trend exists in GDP growth. Furthermore, a unit root test is applied to verify the stationarity of the GDP growth. The stability of the GDP growth series is confirmed by the results of ADF tests, in which the existence of the unit roots can be rejected at the 1% significance level in the models with intercept.

However, the time trend in variance can be revealed by several preliminary analyses. Given that the quarterly GDP growth rates are all positive, to uncover the trend of growth variance, we thus remove the mean from the GDP growth series and regress the square of demeaned GDP growth on a constant and time trend. The results show a significantly negative coefficient on time trend (at the 1% significance level). The significance of trend term declines after the inclusion of the lag terms of dependent variables; however, it is still significant at the 10% level (see last 3 columns of Table 1).

[TABLE 1 HERE]

Major conclusions also hold in the robustness tests using three alternative GDP growth estimates. Table A1, A2, and A3 report the results of regression on a constant, a time trend and its lags using PQA GDP growth, HP-filtered GDP and BP-filtered GDP as dependent variables, respectively. From all of the three tables it can be verified that there is no existing time trend in the level of GDP growth (as well as its first difference), while the variance of GDP growth contains a time trend. Remarkably, once its lags have been included into the regression of GDP growth, the adjusted R square increases dramatically, suggesting that an AR model can well explain the GDP growth process.

4.2 Testing for the Instability of the GDP Growth

We conduct a more rigorous analysis on the instability of the GDP growth process. Following Hess and Iwata (1997), McConnell and Perez-Quiros (2000), as well as Stock and Watson (2002), we simply use the AR(1) model to describe the process of quarterly GDP growth. The equation is given by:

$$\dot{Y}_t = \mu + \phi \dot{Y}_{t-1} + \varepsilon_t, \; E\left(\varepsilon_t^2\right) = \sigma^2, \qquad (3)$$

where $\dot{Y}$, μ, ϕ, ε_t, and σ^2 are the quarterly real GDP growth at time t, constant term, autoregressive coefficient, residual term and residual variance, respectively.

Similar to McConnell and Perez-Quiros (2000), the L statistic developed by Nyblom (1989) and Hansen (1992b) is used to detect the parameter instability in GDP growth process. The null hypothesis of L test states that the parameters in the model are stable over time, which can be rejected by the high values of L statistic. Hansen (1992b) also reports the critical values at different significance level for the null hypothesis of stability of individual parameter and the joint stability of multiple parameters.

Panel A of Table 2 shows that we cannot reject the null hypothesis of stability of both the constant term and autoregressive coefficient over the last three decades. However, the stability of residual variance can be rejected at the 5% significance level. Moreover, we can also reject the null hypothesis of the joint stability of the three parameters concerned. Panel A also shows that the results above are robust to the alternative measures of GDP growth (i.e., HP-filtered GDP and BP-filtered GDP), and that the L statistic in testing BP-filtered GDP shows a significance level better than 1%.

Institutional changes may have occurred in 1992, the time at which the political debate about approaches of economic reform was solved by the south tour speeches of Deng Xiaoping. For the purpose of comparison and further analysis in this essay, the full sample period is split into two sub-periods, i.e., the period prior to and after 1992. However, splitting the sample at an a priori assumed break date is not recommended by Hansen (1992b). Panels B and C of Table 2 show the results of the L test for the two subsamples, respectively.

[TABLE 2 HERE]

Despite one exception, panels B and C indicate that we cannot reject the null hypothesis of stability for all the three parameters (i.e., constant term, autoregressive coefficient, and residual variance) either individually or jointly for both subsamples. Robustness tests on two alternative measures of GDP growth confirm the results of no rejection. The results also show that within each sub-period, AR(1) can model the GDP growth process stably without any structural break.

The significance of residual variance in the second subsample is not stable when the most recent quarters are excluded. If we drop the last quarter (2009 Q4) from the sample, the L statistic of residual variance drops remarkably (from 0.49 to 0.30) and becomes insignificant, whereas the statistics of other parameters become relatively stable. Similar results are observed when more recent quarters (e.g., 4 quarters in 2009) are excluded. Such similar results may be attributed to the prominent V-shape rebound of the Chinese economy in 2009 after the financial crisis. If we look at the two de-trended series (i.e., HP and BP series), the temporary changes can be smoothed, and the L statistic of the residual variance for the second subsample is insignificant.

Substantial difference in residual variance between the two sub-periods is shown in Table 2. The differences in the other two estimates, namely, constant term and autoregressive coefficient, are relatively small. However, we cannot simply and directly conclude that the structural break of GDP growth process is around 1992 by comparing the results in panel B and panel C. This is because the test may be biased towards spurious rejection of the stability hypothesis by splitting the sample at some known important date and by using the conventional critical values (Hansen, 1992b). Consequently, the result in panel A is our major concern because the whole sample of three decades is used and no ex ante break data needs to be chosen.

Briefly, based on the analysis of this section, we cannot reject the stability hypothesis of the constant term and autoregressive coefficient in AR(1) model, whereas the stability of variance and the joint stability of the three parameters concerned can be rejected at the 5% significance level. Certainly, this L test can only confirm the existence of break in variance. The process of detecting the break date is conducted in the following sections.

4.3 Detecting Break Date of GDP Growth

The last section confirms the instability of variance and makes a simple comparison by splitting the full sample into two subsamples using an arbitrary break date assumed ex ante. Here, we further allow the break date of GDP growth to be endogenous and unknown a priori; form this, we then estimate the timing and the significance level of structural change. Again, the GDP growth process is modeled as an AR(1), but with an unknown structural break. Following the specifications below, we investigate whether or not a structural break exists in the residual variance of GDP growth process. We also investigate when it would occur and how much confidence would remain if we reject the stability of variance.

$$\dot{Y}_t = \mu + \phi \dot{Y}_{t-1} + \varepsilon_t, \quad E\left(\varepsilon_t^2\right) = \sigma_1^2 D_{1t} + \sigma_2^2 D_{2t}, \tag{4}$$

where $D_{1t} = \begin{cases} 0 & \text{if } t \le T \\ 1 & \text{if } t > T \end{cases}$, $D_{2t} = \begin{cases} 1 & \text{if } t \le T \\ 0 & \text{if } t > T \end{cases}$, T is the estimated break date, and σ_1^2 and σ_2^2 are the corresponding estimates of the variances in the different subsamples.

The null hypothesis states that the residual variance is constant in the full sample ($\sigma_1^2 = \sigma_2^2$), whereas the alternative hypothesis states that a structural break in variance occurs at time T ($\sigma_1^2 \ne \sigma_2^2$).

If the timing of the structural break is known a priori, the conventional Chow test can be applied to verify whether or not the difference between the subsamples is statistically significant. However, the timing is unknown and endogenous. As a result, the classical chi-square critical values are inappropriate. Furthermore, the parameter to be estimated (i.e., breakdate T) is under the alternative hypothesis, but not under the null, thus implying that the conventional LM, LR, and Wald tests for the null hypothesis do not have standard asymptotic properties. This problem has been solved by Andrews (1993; 2003) and Andrews and Ploberger (1994) with most general statements. In their works, they derive asymptotically the optimal tests for the cases when a nuisance parameter exists under the alternative hypothesis but not under the null. Hansen (1997) further provides a method to calculate the p-values for the test statistics developed by Andrews (1993; 2003) and Andrews and Ploberger (1994).

A function $F_n(T)$ is defined as the Wald or LM statistic of the null hypothesis; it is established for each possible break date T with n observations in the sample. First, the full sample is trimmed to a range of $[T_1, T_2]$, which is usually symmetric ($T_1=1-T_2$). A statistic $\sup F_n$ as well as its critical values are described by Andrews (1993; 2003) as:

$$\sup F_n = \sup_{T_1 \le T \le T_2} F_n(T). \tag{5}$$

The statistic $\sup F_n$ is used to estimate the timing of the structural break T. Moreover, two additional statistics, namely, $\exp F_n$ and $\operatorname{ave} F_n$, are developed by Andrews and Ploberger (1994). These are expressed as:

$$\exp F_n = \ln\left(\frac{1}{T_2 - T_1 + 1} \cdot \sum_{T=T_1}^{T_2} \exp\left(\frac{1}{2} F_n(T)\right)\right), \tag{6}$$

$$\operatorname{ave} F_n = \frac{1}{T_2 - T_1 + 1} \cdot \sum_{T-T_1}^{T_2} F_n(T). \tag{7}$$

In this study, we choose the range of T to be [0.10 n, 0.90 n], indicating that the trimming proportion is symmetrically set as 0.10. Panel A of Table 3 shows the results of the tests for structural beak in the residual variance of GDP growth progress. As mentioned earlier, the null hypothesis states that the variance is constant over time. When all three test statistics are reported, we can see that the null hypothesis of $\sigma_1^2 = \sigma_2^2$ can be rejected at least at the 10% significance level; in addition, the two statistics ($\exp F_n$ and $\text{ave} F_n$) show a strong rejection of the null at the 3% significance level. The estimated date of structural break is in the first quarter of 1993. The existence of structural break in the residual variance is robust to the alternative GDP growth measures (HP-filtered and BP-filtered GDP series); thus, we can reject the null hypothesis of the constant variance in the process of the HP-filtered GDP at least at the 5% significance level. The estimated break dates in the HP-filtered and BP-filtered GDP series, referring to the second quarter of 1992 and the second quarter of 1993, respectively, are just slightly different from the estimated break dates in the FQ GDP growth series.

Following McConnell and Perez-Quiros (2000), we also test whether the constant term or the autoregressive coefficient experience a structural break. This is done in order to examine whether the existence of structural break in residual variance is resulted from the structural breaks in the other parameters of GDP growth process. The following specification is considered:

$$\dot{Y}_t = \mu_1 D_{1t} + \mu_2 D_{2t} + \phi_1 \dot{Y}_{t-1} D_{1t} + \phi_2 \dot{Y}_{t-1} D_{2t} + \varepsilon_t, \quad E(\varepsilon_t^2) = \sigma^2 , \tag{8}$$

where D_{1t} and D_{2t} are defined in the same way as those shown in Equation 4, and the constant residual variance is assumed.

We test the individual structural breaks and a joint structural break in the constant term and autoregressive coefficient. The null hypotheses of individual breaks are defined as $\mu_1 = \mu_2$ and $\phi_1 = \phi_2$ for the constant term and autoregressive coefficient, respectively. The null of the joint break in the two parameters is $\mu_1 = \mu_2, \phi_1 = \phi_2$. Panel B of Table 3 shows the results of the tests for individual breaks and the joint break.

[TABLE 3 HERE]

Panel B of Table 3 clearly shows that we cannot reject the null hypothesis of no break in all tests for the four-quarter GDP growth, including the tests for individual break in constant, individual break in autoregressive coefficient, and a joint break in both parameters. These results are also robust to the alternative test statistics and alternative GDP growth measures, except for the test for a joint break for the BP-filtered GDP.

The result of no break in constant and AR coefficient but a joint break in these two parameters for BP series may arise from the sample selection and outlier effect. The sample span for the BP-filtered GDP is from 1981 Q1 to 2006 Q4[18], and the trimming proportion is 0.10; thus, the first observation for the estimating test statistics is on 1983 Q4, which is also the estimated break date for the joint break in the two parameters. If we choose 0.15 or 0.20 as the trimming proportion, then we cannot reject the null hypothesis of no break in all the tests of constant term and autoregressive coefficient. In addition, the null of constant variance can be rejected at the 1% significance level with 1993 Q2 as the break date.

We can conclude that there are no breaks in the constant term and autoregressive coefficient in the quarterly GDP growth process of China (AR(1) model here). Hence, the existence of structural break in the residual variance does not arise from a change in other parameters in the AR(1) model of GDP growth.

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[18] As previously stated, GDP is BP filtered by choosing 12 leading lags, so that the first and last 12 quarters are dropped after the BP filtering.

Furthermore, we also investigate whether or not more than one break exists in the residual variance of GDP growth process, using a sequential approach given an estimated structural break (Bai and Perron, 1998). We first split the full sample into two subsamples in terms of the estimated timing of structural break reported in Table 3, after which we apply the same test for the structural break in the residual variance to each of the two subsamples. This sequence ends when the null hypothesis of no break cannot be rejected for each subsample. Certainly, due to the limited sample size in our study (maximum 128 quarters), the sequential approach is not applicable if the size of one subsample is too small. As a result, the sequential tests for multiple breaks are only illustrative and cannot provide convincing evidence of the existence of multiple breaks because of the relatively small sample size.

[TABLE 4 HERE]

The results of the sequential tests for more breaks in variance are shown in Table 4. Given the estimated date of structural break (1993 Q1, 1992 Q2, and 1993 Q2 for FQ, HP, and BP series, respectively), the full sample is split into two subsamples, after which the same tests of Andrews (1993; 2003) and Andrews and Ploberger (1994) are applied to each subsample. According to the statistics in Table 4, the null hypothesis of constant variance cannot be rejected in either subsample; hence, an additional structural break does not exist in the AR(1) process of quarterly GDP growth. In addition, the p-values of the test statistics for the first period are relatively smaller than those in the second period, suggesting that the residual variance in the second subsample is more likely stable.

Finally, for the robustness tests, we employ AR models with higher order to characterize the process of GDP growth. We then apply similar tests for the structural breaks, in accordance with the specifications of the GDP growth process. Both the AR(2) and AR(3) models are considered. The results of the tests for structural breaks in variance are reported in Table 5. Panel A reproduces the top panel of Table 3, and panels B and C report the test results for the AR(2) and AR(3) models, respectively. The null of constant variance can be rejected at least at the 10% significance level, even employing AR models with higher orders. However, there are slight differences in the timing of structural break. The test results for HP-filtered GDP using the AR(1), AR(2), and AR(3) models report the identical timing of structural break in variance (1992 Q2), whereas those for four-quarter GDP growth reach more or less the same conclusions (1993 Q1 and 1993 Q3). Moreover, we also conduct tests for the structural breaks in constant term and AR coefficient in the AR(2) and AR(3) models. The results reported in Tables A4 and A5 show that we cannot reject the null hypothesis of no individual break either in constant or in autoregressive coefficient for all cases considered. Several test statistics suggest that a joint break exists in these two parameters, which however cannot be inferred from all the test statistics and from all alternative GDP growth measures.

[TABLE 5 HERE]

5 Regime Switching of GDP Growth

Using the statistics developed by Andrews (1993; 2003) and Andrews and Ploberger (1994), we have shown in the last section that there is a statistically significant structural break in the variance of China's GDP growth, which is likely to occur in 1992 or 1993. Here, we investigate and detect the declining volatility of GDP growth using an alternative approach, namely, the Markov

Switching model, which features the time-series behavior as regime shifts between different states.

The Markov Switching model is non-linear and assumes that the parameters modeling an observed time series depend on an unobservable state variable associated with different regimes. This model has been employed and further developed by the influential work of Hamilton (1989) to detect the regime switch of the GDP growth between two states governed by a Markov process, namely, the high growth regime and the low growth regime. Hamilton's subsequent efforts (Hamilton, 1990; Hamilton and Susmel, 1994; Hamilton, 1996) as well as other related studies further extend this approach, applying it to characterize business cycles, such as the studies of Durland and McCurdy (1994), Filardo (1994), Kim and Nelson (1999), and McConnell and Perez-Quiros (2000).

We also employ the Markov Switching models to characterize the dynamics of China's GDP growth. First, the process of GDP growth is modeled as AR(p), after which the two states of the Markov Switching model are introduced into the process of AR(p). The methodology of Markov Switching AR(p) model is described briefly below.

5.1 Model Description

In the present work, GDP growth is modeled as an AR(p) if there is no regime shift in its process. Two kinds of AR(p) models are considered here, namely, the AR(p) model with intercept and the AR(p) model with mean. The former continues to consider the conventional AR model, which is employed in the discussions in previous sections, whereas the latter is in accordance with the specification of Hamilton (1989). Certainly, the models with intercept term and with mean are identical when $\mu=\delta=0$. Consider the following general representation of a Markov Switching model in AR(p):

$$\dot{Y}_t=\mu_{S_t}+\sum_{i=1}^{p}\phi_{i,S_t}\dot{Y}_{t-i}+\sigma_{S_t}\varepsilon_t\,,\;\; \varepsilon_t\sim i.i.d.N(0,1)\,, \tag{9}$$

$$\dot{Y}_t=\delta_{S_t}+\sum_{i=1}^{p}\phi_{i,S_t}\left(\dot{Y}_{t-i}-\delta_{S_t}\right)+\sigma_{S_t}\varepsilon_t\,,\;\; \varepsilon_t\sim i.i.d.N(0,1)\,, \tag{10}$$

where $\dot{Y}_t$ is the real GDP growth, while μ_{S_t}, δ_{S_t}, and $\sigma^2_{S_t}$ are the intercept term, mean value and residual variance of the GDP growth conditioned in the unobserved Markov Switching state variable S_t, respectively.

Let there be 2 states (i.e., S_t = 1 or S_t = 2). Subsequently, the 2-state unobserved variable S_t and the transition between the two states are governed by a Markov Chain process, in which the probability of being in a particular state at time t depends only on the state at time t-1. The matrix P of the transition probabilities is defined by Hamilton (1994) as follows:

$$P=\begin{pmatrix} p_{11} & p_{12} \\ p_{21} & p_{22} \end{pmatrix}=\begin{pmatrix} P(S_t=1\,|\,S_{t-1}=1) & P(S_t=1\,|\,S_{t-1}=2) \\ P(S_t=2\,|\,S_{t-1}=1) & P(S_t=2\,|\,S_{t-1}=2) \end{pmatrix}, \tag{11}$$

where p_{ij} is the probability of regime switching from state j at time t-1 to state i at time t, and $p_{11}+p_{21}=p_{22}+p_{12}=1$.

In particular, if $p=1$, $\sigma_1^2=\sigma_2^2$ and $\delta_1<\delta_2$, the Markov Switching AR(1) model with mean is simplified as the one used in Hamilton (1989), in which he assumes two unobserved states (i.e., the higher growth δ_2 and the lower growth δ_1) switch with constant variances σ^2.

Given that the analyses in previous sections suggest that there is a structural break in variance, rather than constant and autoregressive coefficient of an AR model characterizing the process of GDP growth, the first specification we consider here assumes that the intercept term and the autoregressive dynamics are constant and state independent, whereas the variance depends on the unobserved state variable. The MSH-1 model is expressed as:

$$\dot{Y}_t = \mu + \sum_{i=1}^{p} \phi_i \dot{Y}_{t-i} + \sigma_{S_t} \varepsilon_t , \ \varepsilon_t \sim i.i.d.N(0,1). \tag{12}$$

For further comparisons, the second specification relaxes the restriction on invariant constant term, and assumes that the constant term and variance depend on the unobserved state variable; meanwhile, the autoregressive coefficient proves to be state independent. The MSIH model (Clements and Krolzig, 1998) is thus expressed as:

$$\dot{Y}_t = \mu_{S_t} + \sum_{i=1}^{p} \phi_i \dot{Y}_{t-i} + \sigma_{S_t} \varepsilon_t , \ \varepsilon_t \sim i.i.d.N(0,1). \tag{13}$$

Hamilton (1989) and McConnell and Perez-Quiros (2000) employ an alternative model setting, in which the AR process incorporates an unconditional mean instead of a constant term. We also consider these alternative models, using the following two specifications. The second one (Equation 15) is similar to the one used in McConnell and Perez-Quiros (2000); however, the difference is that they further allow two regimes of mean growth given the state of variance. Equations 14 and 15 represent the MSH-2 and MSMH models, respectively:

$$\dot{Y}_t = \delta + \sum_{i=1}^{p} \phi_i \left(\dot{Y}_{t-i} - \delta_{S_t} \right) + \sigma_{S_t} \varepsilon_t , \ \varepsilon_t \sim i.i.d.N(0,1), \tag{14}$$

$$\dot{Y}_t = \delta_{S_t} + \sum_{i=1}^{p} \phi_i \left(\dot{Y}_{t-i} - \delta_{S_t} \right) + \sigma_{S_t} \varepsilon_t , \ \varepsilon_t \sim i.i.d.N(0,1). \tag{15}$$

The parameter estimations can be made through the Maximum Likelihood (ML) method and Expectation Maximization (EM) algorithm (Hamilton, 1990; Hansen, 1992a; Hamilton, 1994), or through the recently developed Bayesian inference with Gibbs sampling (Kim and Nelson, 1999). We employ the first approach to estimate our models.

5.2 Results of the Markov Switching Model

For simplicity and for comparing the results in the previous sections, we first consider an AR(1) model to characterize the GDP growth process. For instance, for the four-quarter GDP growth, the AR(1) model dominates the AR(2) model in terms of different criterions (AIC, HQIC, or SBIC) when we assume there is no structural break in models. However, if we allow more lags in the AR models, the best lag order chosen by the information criterions is not likely to converge. Thus, we focus on AR models with lag orders 1 and 3.

The conventional AR(1) model with constant term is first considered. Table 6 shows the results of parameter estimations and several tests for MSH and MSIH models with AR(1). The first panel summarizes the parameter estimations, while panels B–E show the residual diagnostic, instability tests, transition probability matrix and the regime classification, respectively.

The first column of Table 6 shows that the skewness and kurtosis of AR(1) residuals are significantly different from those of normal distribution. The Jarque-Bera test results also suggest that we can reject the null hypothesis of the normal distribution of residuals at the 1% significance level. Panel C of AR(1) reproduces the results of the instability test in previous sections, indicating a strong rejection of the null hypothesis of constant variance and joint stability of parameters. The Ljung-Box statistic is used in this section to test the significance of autocorrelations of standardized residuals. Here, $Q_1(8)$ and $Q_2(8)$ correspond to Ljung-Box statistics for the first 8 lags with the null hypothesis of no autocorrelation for the standardized residuals and squared standardized residuals, respectively. Both statistics indicate that we can reject the null hypothesis of zero autocorrelation at the 5% significance level. All the results of residual diagnostic tests are evident in the non-linearity and instability of parameters in the AR(1) model.

[TABLE 6 HERE]

The first specification, the MSH model, assumes that only residual variances depend on the unobserved state variable. The second and third columns show the results of the variance-switching model. We can see that the higher-variance state (Regime 1) shows a variance that is more than twice as large as the variance in the lower-variance state (Regime 2). The estimates of all parameters in this specification are statistically significant at least at the 5% significance level. The log likelihood also increases from -213.87 in AR(1) model to -202.03, suggesting that the MSH model improves the explanation power compared with the AR(1) model. Furthermore, the results of the residual diagnostics also confirm the improvement. The skewness and kurtosis of the residual are reduced significantly relative to the actual data as well as the AR(1) model. The results of the Jarque-Bera test further suggest that we cannot reject the null hypothesis of the normal distribution of residual for the MSH model. Despite the fact that the Ljung-Box statistic still illustrates significant rejection of no autocorrelations, the values decrease remarkably. The evidence provided by the instability test also suggests the improvement of the MSH model, and that the null hypothesis of a single break or a joint break in each parameter cannot be rejected.

The diagonal elements of transition probability matrix reported in panel D lie close to 1; this indicates the high persistence of both regimes and suggests that if the economy is in Regime 1 or Regime 2 in the current period in the MSH model, then it is most likely to remain in its current state in the next period. The smoothed probability[19] of being in a higher-variance state (Regime 1) is plotted in Figure 5. Hamilton (1989) proposes an approach in detecting the date of regime switching, in which an observation is fitted to a state if the corresponding smoothed probability is higher than 0.50. Accordingly, the regime classification is made. The results are reported in panel E.

[FIGURE 5 HERE]

The two regimes, the higher-variance regime (Regime 1) and the lower-variance regime (Regime 2), switch over in the last three decades. It suggests that there exists a structural break in the variance of the GDP growth process (Figure 5). Despite the unstable regime switch in the first 3 observations, there is a highly significant structural break in the first quarter of 1993, when the smoothed probability of being in Regime 1 drastically drops below 0.5 for the first time. Prior to the first quarter of 1993, the GDP growth of China can be modeled as a process with higher variance, whereas it experiences lower volatility after that quarter. Interestingly, the date of the structural break detected using the Markov Switching model, i.e., 1993 Q1, is identical to the date of the structural break estimated using the approaches proposed by Andrews (1993; 2003) and Andrews and Ploberger (1994). Identical results using different approaches indicate that the existence and timing of structural breaks in variance are robust. Moreover, the smoothed probability of higher-variance regime has increased remarkably in the recent two years, which can

[19] The smoothed probabilities for each time t are calculated based on the information of complete sample T, whereas the filtered probabilities are calculated based on the information up to time t.

be attributed to the recent global financial crisis. The identical results also suggest that the era of over 15 years with less volatile GDP growth may end if China is unable to recover from the crisis and sustain its economic growth successfully in the coming years.

Next, we relax the restriction on the invariant constant term between the two regimes and conduct parameter estimation and relative tests for our second specification (i.e., the MSIH model) similar to those in the MSH model. The results for MSIH model are shown in the last two columns of Table 6. The smoothed probabilities of Regime 1 are illustrated in Figure 6. All estimated parameters are statistically significant, and the constant terms in different regimes are slightly different, i.e., 1.34 versus 1.14. The estimated autoregressive coefficient and residual variance are nearly the same with those in the MSH model. The results of residual diagnostics and instability test also reveal that the null hypothesis of the normal distribution of residual cannot be rejected. Meanwhile, the direct illustration of regime switching of GDP growth can be found in Figure 6, which shows an almost identical pattern with that in Figure 5. A one-time structural change from a higher variance regime to a lower variance regime occurred during the years 1992–1993. The slight change in constant term also suggests a slight change in the mean value of economic growth.

In comparing the results for the MSH and MSIH models, relaxing the restriction on constant term only slightly improves the explanation power, along with the almost identical estimation results of the autoregressive coefficient and residual variance. Due to the slight difference in constant terms between the two regimes, we can conclude that the regime switching in variance is the primary characteristic of China's GDP growth over the last three decades. A drastic increase in the probability of low-variance regime is detected in the last quarter of 1992. Furthermore, the transition probabilities indicate the persistence of both regimes.

[FIGURE 6 HERE]

We use the Markov Switching model with mean (Hamilton, 1989; McConnell and Perez-Quiros, 2000) in order to check the robustness of our results. Table A6 shows the results for the MSH-2 and MSMH models with AR(1). Clearly, the results in Tables 6 and A6 are almost identical. There is no doubt that the results for models with constant term and mean are consistent, because we use AR(1) as the analysis framework and all the estimated parameters are highly significant. The mean value is calculated by dividing the constant term by 1 minus the autoregressive coefficient in terms of recursive method and is expressed as:

$$\delta = \frac{\mu}{1-\phi}. \tag{16}$$

Moreover, we conduct the same analysis on the BP-filtered GDP series. We can check whether or not the presence of regime switching is affected by the choice of volatility frequency because the BP-filtered series has filtered out the highest and lowest frequency fluctuations. In this essay, the BP-filtered GDP focus only on volatility with periods of 6 to 32 quarters, and the first and last 12 quarters are dropped during the filtering procedure. Table 7 shows the results of tests for the BP-filtered GDP series. Meanwhile, the smoothed probability of high-variance regime is illustrated in Figure 7.

Table 7 shows that after filtering out the highest and lowest frequencies, the main findings in Table 6 still hold, except for some minor differences. First, the estimated constant term becomes insignificant in all models for the BP series. Second, the higher-variance regime experiences a variance, which is more than four times as large as that in the lower-variance regime. Moreover, there are two exceptional periods, the last quarter of 1990 and the last quarter of 2006, when GDP growth suffers a partial and unsuccessful regime switching. Given that the last observation is 2006 Q4 for BP series, we cannot conclude directly that the low-variance regime ends at that time. A sample with wider time span, for instance, the four-quarter series, suggests that the increase of probability of high variance regime in 2006 is temporary, and a more drastic regime shift exists around the years 2008–2009. Despite the above discrepancies, a significant regime shift is also found for the BP-filtered GDP series; in addition, the timing of structural change (1993 Q2) is just slightly different from that for four-quarter GDP growth (1993 Q1).

[FIGURE 7 HERE]

[TABLE 7 HERE]

Finally, we examine the effects of the lag order of the AR model by using AR(3) to model China's GDP growth (MSH and MSIH with 3 lags as well). Next, we conduct the same analyses as those done for the AR(1) models as shown above. Major results are summarized in Table 8 for both four-quarter and BP-filtered series. Figures 8 and 9 illustrate the smoothed probability of higher-variance regime in MSH model for four-quarter GDP growth and BP-filtered GDP series, respectively.

Most of the results in Table 7 are qualitatively the same with those in Table 6, except for some discrepancies in the timing of structural break in variance. Under the AR(3) model setting, the four-quarter GDP growth experiences a structural shift in variance in the middle of 1990, whereas the BP-filtered GDP switches its variance in the second quarter of 1992. It is noteworthy that, with higher lag orders, the estimated timing of structural shift is earlier than those with lower lag orders, 3 years earlier for four-quarter series, and 1 year earlier for BP-filtered series. Furthermore, the observed temporary shifts[20] in the BP-filtered series with AR(1) model disappear when the AR(3) models are employed.

[FIGURE 8 HERE]

[FIGURE 9 HERE]

[TABLE 8 HERE]

Previous sections have provided abundant and robust evidence of the instability of variance of China's GDP growth, as well as the presence of one-time structural break in the variance of economic growth. Further analyses reveal that the timing of structural shift or regime switching is likely to occur in the early 1990s. Most emprical results suggest that the break dates may be late 1992 or early 1993, or even a little earlier considering the alternative model settings. These findings are robust to the alternative measures of GDP growth, namely, four-quarter, HP-filtered, and BP-filtered series. Moreover, the findings are also robust to the alternative approaches of structural change, e.g., Nyblom-Hansen's L test (Nyblom, 1989; Hansen, 1992b), SupF tests for structural break (Andrews, 1993; Andrews and Ploberger, 1994; Andrews, 2003), and Markov Switching AR models (Hamilton, 1989; Kim and Nelson, 1999; McConnell and Perez-Quiros, 2000), to name a few. Statistically speaking, China's GDP growth experienced a one-time structural shift or regime

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[20] Temporary shifts are found in the end of 1990 and the last quarter of 2006 for the BP-filtered GDP in models with 1 lag.

switching from higher variance to lower variance in the early 1990s, which may have occurred in the years 1992–1993.

Nevertheless, the univariate analysis of the GDP growth of China only provides a limited picture of the dynamics of economic growth itself. This kind of analysis can only answer the question as to whether or not the volatility of the GDP growth has become less volatile over the last three decades or if there exists a structural change or regime shift in the process of economic growth. The following sections discuss the sources of the decreased volatility of GDP growth using different methods. According to the analyses above, the volatility of economic growth has evidently experienced a one-time structural change in the years 1992–1993. Thus, we separate the whole sample into two sub-periods, namely, 1978–1992 and 1993–2008. The following sections employ several decomposition approaches from different perspectives to demonstrate the contributions of the decomposed factors to the aggregate volatility. The proceeding sections also investigate whether or not the differences in the growth and volatility contribution of the decomposed factors for the two sub-periods are significant.

6 Sources: Production Perspective

6.1 Labor Productivity Decomposition

First, we begin with simple labor productivity decomposition. Supposing that the output Y is the product of labor (L) and average labor productivity (y, ALP), then the simple decompositions of economic growth and growth variance in terms of labor productivity are:

$$\dot{Y}_t = \dot{L}_t + \dot{y}_t, \tag{17}$$

$$\mathrm{var}\left(\dot{Y}_t\right) = \mathrm{var}\left(\dot{L}_t\right) + \mathrm{var}\left(\dot{y}_t\right) + 2\,\mathrm{cov}\left(\dot{L}_t, \dot{y}_t\right), \tag{18}$$

where $\dot{Y}_t$, $\dot{L}_t$, and $\dot{y}_t$ indicate the growth rates of GDP, labor and average labor productivity, respectively. The values of the growth rates are calculated by taking the first difference of the log values of the variables concerned. Here, var and cov represent variance and covariance, respectively. Similar to Stiroh (2009), each term on the right hand side of Equation 18 is regarded as the volatility contribution of corresponding component.

Here, we use the annual data on the real GDP growth and China's employment growth over the years 1978–2008. Figure 10 illustrates the growth rates of GDP, employment, and labor productivity over the last three decades.

[FIGURE 10 HERE]

As stated previously, we split the whole sample into two sub-periods, 1978–1992 and 1993–2008. Table 9 shows the differences in mean growth rates and volatility between the two sub-periods, along with the significance levels of the changes. To calculate the statistical significance of the difference in mean growth rates, we conduct a t-test for the null hypothesis of equal mean growth rates of the two sub-periods when unequal variances are allowed. For the difference in variances term, we use Levene's robust test statistic to test the equality of variances between the two sub-periods. This has been proven to be robust under the normality of the underlying distributions (Stiroh, 2009). For the difference in covariance term, a two-sample test for the null of equal covariances is conducted, whereas we implement a two-sample test for the null of equal correlation coefficient for the difference in correlation coefficient (Lawley, 1963). As Stiroh (2009) argues, the tests of GDP, employment, and labor productivity are not independent because these three variables are associated according to the decomposition approach. However, they at least draw a picture of statistical significance of the individual differences.

Similar to the results of previous sections, no evidence of changes in the mean growth rate of GDP is found, making the variances more directly comparable. However, as Figure 10 and Table 9 indicate, the significant decline in employment growth as well as the significant increase in labor productivity in the second sub-period is suggestive. The mean growth rate of employment drops from 2.45% to 0.99%, whereas that of labor productivity increases from 6.52% to 8.68% after 1992. The reason why China's employment growth experienced a significant decline may be attributed to both demographic and statistical reasons. First, the drastic drop of employment growth after 1990s reflects the sharp decline in population birth rates in 1970s (Bosworth and Collins, 2008). Another underlying reason may lie on the changes of statistical coverage of employment (Holz, 2009a).

It is noteworthy that a large decline in volatility of growth is found in all components except the covariance between labor and productivity. The decline in GDP volatility mainly results from the decline in volatility of labor productivity in terms of magnitude. Moreover, 97% of the decline in output volatility can be attributed to the contribution of variances of labor productivity. The rolling variance decomposition with a window of 5 years is shown in Figure 11, which provides an illustrative picture of the changes of decomposition components of output volatility. Output volatility mainly reflects the variances of labor productivity in terms of magnitude, whereas the sizes of employment volatility and covariance of employment and labor productivity are relatively small.

[FIGURE 11 HERE]

The covariance term in Table 9 is the combination of the correlation coefficient between employment and labor productivity, and their standard deviations. We also compare the raw correlation between these two variables for the two sub-periods and the change between the two sub-periods. This is done so that the change in co-movements of employment and productivity can be better investigated. The raw correlation between labor and productivity is small and insignificant in the first sub-period. Subsequently, the correlation becomes significant and negative in the second period. However, the correlation differences between the two sub-periods are not significant.

[TABLE 9 HERE]

6.2 Growth Accounting Decomposition

Following Stiroh (2009), we extend the decomposition approach under a growth accounting framework. Suppose that the output Y is produced by the labor input L, capital services K, and technology A. The production function is constant return to scale (CRS) with Hicks-neutral augmented technology A. The growth accounting procedure is described as follows:

$$Y = Af\left(L,K\right) = AL^{\alpha}K^{1-\alpha}, \tag{19}$$

$$\dot{Y}_t = \dot{A}_t + \alpha_t \dot{L}_t + \left(1-\alpha_t\right)\dot{K}_t, \tag{20}$$

where $\dot{Y}_t$, $\dot{L}_t$, $\dot{K}_t$, and $\dot{A}_t$ indicate the growth rates of GDP, labor, capital and TFP, respectively. The first three items are calculated by taking the first difference of log value of the variable concerned, whereas the last one is calculated as the residual of growth accounting. The output elasticity of labor α_t is calculated as the output share of labor compensation.

The variance of output growth can be decomposed in terms of growth accounting approach if we treat all terms in growth accounting as random variables. The output volatility can be decomposed into volatilities of the three variables in the right hand side of Equation 20 and their pairwise covariances. Each term in the right hand side of Equation 21 is also regarded as volatility contribution.

$$\operatorname{var}\left(\dot{Y}_t\right)=\sum_{i=1}^{3}\operatorname{var}\left(X_{i,t}\right)+\sum_{i=1}^{3}\sum_{j>i}^{3}2\operatorname{cov}\left(X_{i,t},X_{j,t}\right), \tag{21}$$

where $X_{i,t}$ indicates the three growth accounting items, namely, TFP growth ($\dot{A}_t$), labor growth contribution ($\alpha_t\dot{L}_t$), and capital deepening contribution ($(1-\alpha_t)\dot{K}_t$).

Data on GDP, employment, and capital are constructed as the previous corresponding section states. The output elasticity of labor α_t, i.e., the share of labor compensation in the output, is computed according to the data on GDP by income approach and varies over time in terms of the relative share of compensation of employees in GDP.[21] We obtain the national data by adding up all provincial data and dividing the sum of GDP by income approach by the sum of compensation of employees. This is because only the provincial data on GDP by income approach are available. Growth accounting decomposition is conducted for the years 1978–2008. The results of growth accounting are shown in Figure 12, which also demonstrates the respective growth contributions of labor, capital, and TFP.

[FIGURE 12 HERE]

[21] In the Chinese statistical system, the GDP by income approach is calculated by adding the following four components: (1) compensation of employees, (2) net taxes on production, (3) depreciation of fixed assets, and (4) operating surplus. The share of labor compensation in output is calculated as the proportion of compensation of employees in GDP by income approach.

Table 10 shows the results of growth accounting decomposition. The left panel provides the results of growth decomposition, while the right panel shows the results of volatility decomposition. The left panel shows that the growth contributions of both labor and capital input show significant changes between the two sub-periods but in opposite direction, whereas there is no change in the mean of TFP growth. Figure 12 also provides a visual view of the growth contributions of labor and capital, showing a declining and increasing trend, respectively.

The right panel of Table 10 indicates that, all other volatility components experience a significant decline except for the volatility contributions of the variance of capital growth and the covariance between labor and TFP growth. Although the direct contribution of employment is statistically significant, its magnitude is economically small. In contrast, the volatility contribution of TFP is both significant and economically large. The direct contribution of capital also shows a mild but insignificant increase, whereas the change of covariance contribution of the other two factors (labor and TFP) is significantly positive but economically small. The variance of TFP and the covariance between capital and TFP contribute 68.7% and 30.8% of the decline in output volatility, respectively. Figure 13 also shows the rolling results of variance decomposition from a growth accounting perspective. A window of 5 years is used here. As a result, the changes of volatility contribution of TFP and the covariance between capital and TFP dominate the dynamics of output volatility in terms of magnitude. In addition, these two components are likely to co-move with the GDP volatility.

[TABLE 10 HERE]

[FIGURE 13 HERE]

The pairwise correlations and their changes are also shown in Table 10. The correlation between labor and capital and that between capital and TFP both decrease significantly; the former becomes significantly negative, whereas the latter becomes small and insignificant.

We can conclude that the remarkable decline in the output volatility can be primarily attributed to the statistically significant contribution of the declining volatility of TFP as well as the declining correlation of capital input and TFP. The results also suggest that both the increasing stability of TFP growth and the declining correlation of capital input and TFP have crucial effects on the decline in output volatility of the Chinese economy. The results are consistent with the conclusion of He, Chong and Shi (2009), indicating that TFP is the best explanatory factor of the aggregate business cycles.

6.3 Sector Decomposition: Three Sectors

To uncover the specific sources of the decline in output volatility, we further employ the data of the three main economic sectors to decompose the volatility change into the contributions of volatility within sectors and between sectors. For instance, if the decline in variances within some sectors plays an important role in explaining the aggregate decline, it may be associated with a sector-specified technology shock or economic structure changes. In contrast, if the changes of covariances across sectors are crucial, an exogenous common shock or good luck explanation may dominate (Stock and Watson, 2002). The approach of sector decomposition is introduced briefly below.

The aggregate output can be expressed as the sum of the value-added of the three main economic sectors, namely, the primary, secondary, and tertiary sectors. Moreover, the output growth is the weighted sum of the sectoral value-added growth (Jorgenson and Stiroh, 2000; Stiroh, 2009):

$$\dot{Y}_t = \sum_{i=1}^{3} s_{i,t}\dot{V}_{i,t}, \tag{22}$$

where $s_{i,t}$ is the sectoral weight, which is calculated as the two-period average nominal share of the sectoral value-added in aggregate output. In each item in Equation 22, $s_{i,t}\dot{V}_{i,t}$ is the sectoral growth contribution to aggregate output growth.

In terms of the weighted summation of sectoral value-added growth, the variance of aggregate growth can be attributed to the sum of variances of the sectoral growth contribution and the sum of covariances between sectors[22]:

$$\mathrm{var}\left(\dot{Y}_t\right) = \sum_{i=1}^{3} \mathrm{var}\left(s_{i,t}\dot{V}_{i,t}\right) + \sum_{i=1}^{3}\sum_{j>i}^{3} 2\,\mathrm{cov}\left(s_{i,t}\dot{V}_{i,t}, s_{j,t}\dot{V}_{j,t}\right). \tag{23}$$

Furthermore, sectoral value-added is considered the product of sectoral labor and sectoral labor productivity, $V_{i,t} = L_{i,t}v_{i,t}$. Therefore, the aggregate output growth can be decomposed into the contributions of sectoral labor growth and sectoral labor productivity growth:

$$\dot{Y}_t = \sum_{i=1}^{3} s_{i,t}\dot{L}_{i,t} + \sum_{i=1}^{3} s_{i,t}\dot{v}_{i,t}. \tag{24}$$

The sectoral labor productivity decomposition of variances is described as follows:

[22] It should be noted that the volatility dynamic of each sector may be different from that of GDP growth. This approach is employed to discuss the relative contribution of the changes of variances and covariances of sectoral growths in the decline of the volatility of GDP growth. The volatility of each sectoral growth may deserve further investigation, which however is out of the scope of this study. This concern is also applicable to the following sections, including the volatility decomposition from the demand and regional perspectives.

$$
\begin{aligned}
\operatorname{var}\left(\dot{Y}_t\right) &= \sum_{i=1}^{3}\operatorname{var}\left(s_{i,t}\dot{L}_{i,t}\right)+\sum_{i=1}^{3}\operatorname{var}\left(s_{i,t}\dot{v}_{i,t}\right) \\
&+\sum_{i=1}^{3}\sum_{j>i}^{3}2\operatorname{cov}\left(s_{i,t}\dot{L}_{i,t},s_{j,t}\dot{L}_{j,t}\right)+\sum_{i=1}^{3}\sum_{j>i}^{3}2\operatorname{cov}\left(s_{i,t}\dot{v}_{i,t},s_{j,t}\dot{v}_{j,t}\right), \\
&+\sum_{i=1}^{3}\sum_{j=1}^{3}2\operatorname{cov}\left(s_{i,t}\dot{L}_{i,t},s_{j,t}\dot{v}_{j,t}\right)
\end{aligned}
\tag{25}
$$

where the first two summations are the direct variance contributions of the weighted labor growth and weighted labor productivity growth of each sector, and the three covariance summations (i.e., labor-labor, productivity-productivity, and labor-productivity) are for all sector pairs.

It is noteworthy that the first two covariance summations (labor-labor and productivity-productivity) only comprise between-sector effects, whereas the last covariance summation (labor-productivity) comprises both between- and within-sector effects. As a result, the last covariance summation can be further decomposed into a between-sector component and a within-sector component (Stiroh, 2009):

$$
\begin{aligned}
&\sum_{i=1}^{3}\sum_{j=1}^{3}2\operatorname{cov}\left(s_{i,t}\dot{L}_{i,t},s_{j,t}\dot{v}_{j,t}\right) \\
&=\sum_{i=1}^{3}2\operatorname{cov}\left(s_{i,t}\dot{L}_{i,t},s_{i,t}\dot{v}_{i,t}\right)+\sum_{i=1}^{3}\sum_{j\neq i}^{3}2\operatorname{cov}\left(s_{i,t}\dot{L}_{i,t},s_{j,t}\dot{v}_{j,t}\right)
\end{aligned}
\tag{26}
$$

The first and second covariance summations in Equation 26 represent the covariances of labor and productivity for a specific sector (within-sector) and those between different sectors (between-sector), respectively.

This study uses the data on value-added and employment of the three main economic sectors for the years 1978–2008 to conduct sector decomposition. Figure 14 shows the growth contributions of the three main economic sectors, while Figures 15 and 16 demonstrate the rolling results of variance decomposition with a window of 5 years. The results of further decomposition in terms of labor productivity are shown in Figures 17, 18, and 19.

The comparisons of the two sub-periods are summarized in Table 11. The first panel shows the sectoral value-added decomposition in accordance with Equation 22 and Equation 23, whereas the second panel shows the sectoral labor productivity decomposition following Equations 24-26.

[FIGURE 14 HERE]

[FIGURE 15 HERE]

We can see from the top panel of Table 11 that although the aggregate economic growth shows no evidence of significant change between the two sub-periods, the growth contributions of the primary and tertiary sectors experience drastic changes, i.e., a decline for the former and an increase for the latter. However, in terms of magnitude, the significant changes of the mean growth rates of the primary and tertiary sectors cancel out. Hence, the change of mean growth rate of the aggregate output is roughly in line with that of the secondary sector. The results further indicate that over the last three decades, the growth contribution of the secondary sector (mainly manufacturing and construction) is relatively stable, whereas that of the primary sector (agriculture) becomes trivial in the second sub-period. The tertiary sector (services), however, becomes increasingly important in sustaining China's economic growth.

Figure 14 illustrates the decreasing and increasing growth contribution from the primary and tertiary sectors, respectively. The growth contribution of the secondary sector is pro-cyclical, whereas those of the primary and tertiary sectors are relatively stable, especially after the early 1990s. The differences in the growth contribution of the three sectors suggest that, to a certain extent, the primary and tertiary sectors serve as the stabilizers of the aggregate business cycles during the continuous industrialization of the Chinese economy (Xu, 2002).

The top panel also shows that all terms of variance decomposition, except for the covariance between the primary and secondary sectors, show a significant decline after 1992.[23] Among all the terms of variance decomposition, the direct contribution of the secondary sector, and the covariance between the secondary and tertiary sectors are relatively large, accounting for 43.5% and 44.4% of the decline in aggregate volatility, respectively. As shown in Figure 15, the two components not only dominate the changes of aggregate output volatility in terms of magnitude, but also co-move with the variance dynamics of the aggregate GDP.

[FIGURE 16 HERE]

Generally, both the within and between effects play an important role in explaining the declining volatility of the aggregate output growth. However, the within effect dominates in terms of magnitude, and nearly 77% of the decline in the volatility of aggregate output growth can be attributed to the direct contributions of sectoral variances. Figure 16 provides a visual illustration of the volatility contributions of within and between effects. The result is different from the evidence of the US (Stiroh, 2009), in which the covariances (between effect) account for the 80% of the aggregate volatility. As a result, we may reach the conclusion that the decline in aggregate output

[23] The volatility contribution of the covariance between the primary and secondary sectors increases significantly after 1992, and the magnitude is far from negligible. We can see that the correlation between the primary and secondary sectors turns to be 0.52 in the second sub-period from -0.32 in the first one, while the change is statistically significant.

volatility can be mainly traced to idiosyncratic shocks of individual sectors or shocks with heterogenous effects on different sectors, rather than common shocks across sectors.

[FIGURE 17 HERE]

[FIGURE 18 HERE]

Figures 17–19 and the bottom panel of Table 11 show the results of sectoral labor productivity decomposition following Equations 24–26. A decline in aggregate sectoral employment growth and an increase in aggregate sectoral labor productivity are illustrated in Figure 17. In addition, Table 11 shows the statistically significant changes of both growth rates between the two sub-periods.

Figure 18 and Table 11, meanwhile, show that labor productivity growth becomes less volatile within sectors in the second sub-period, whereas the volatility of employment growth remains relatively stable in general. The variances of labor growth and productivity growth contribute 46% of the decline in aggregate output volatility, whereas other various covariances account for the remaining 54%. Both variances and covariances components of sectoral labor productivity decomposition play important roles in the decline in aggregate output volatility, as shown in Figure 19.

Moreover, the between-sector covariances of employment and those of labor productivity dominate the decline in total covariances, accounting for 85.6% of the decline in total covariances, and hence 46.2% of the decline in volatility of the aggregate output growth. As a result, the covariances between labor and labor productivity mildly decrease (0.57), accounting only for 14.4% of the decline in total covariances. However, according to further decomposition, the covariances between employment and labor productivity within sectors experience an economically large decline (2.32), whereas those between sectors show a remarkable increase (1.75).

The results in this section suggest that the drastic drop of aggregate output volatility primarily reflects the direct contribution of significant decline in variances of sectoral growth, which can be traced to significant changes in variances of sectoral labor productivity and the covariances of labor and productivity within sectors.

[TABLE 11 HERE]

[FIGURE 19 HERE]

Next, we look into the pairwise correlation coefficients of sectoral growth contributions than their covariances. The rolling pairwise correlation coefficients with a window of 5 years are calculated and plotted in Figure 20.

As shown in Figure 14, the growth contribution of the secondary sector is highly pro-cyclical, thereby dominating the dynamics of aggregate volatility. The results of the pairwise correlations between the secondary sector and the other two sectors are very interesting. The rolling correlation between the primary and secondary sectors shows an increase from a negative value to a roughly positive one after the middle 1990s, suggesting that the growth contribution of the primary sector has become somewhat pro-cyclical despite a recent declining trend in its correlation with that of the secondary sector. In comparison, the rolling correlation of the growth contribution of the secondary and tertiary sectors shows a different picture, in which the pairwise correlation is significantly positive and stable before the mid-1990s, around 0.9–1.0. The positive pairwise correlation indicates that the growth contribution of the tertiary sector highly co-moves with that of the secondary sector in the first half of the reform period, suggesting that both demonstrate a pro-cyclical pattern. The correlation varies significantly after the mid-1990s, showing a sharp decline despite a recent increase. Moreover, we can also conclude that the increase of covariances between the primary and secondary sectors shown in Figure 15 and Table 11 is mainly driven by their rising correlation,[24] whereas the decline in the covariances between the tertiary and secondary sectors reflects their decreasing correlation, rather than their reduced variability.

[FIGURE 20 HERE]

Similar to Stiroh (2009), we also compute the rolling 5-year weighted average correlation among the sector pairs for weighted growth of value added, employment, and labor productivity, following Equations 27 and 28, which use the equal weight and average nominal value-added weight, respectively. These are expressed as:

$$\bar{\rho}_{B,X,U}=\sum_{i=1}^{3}\sum_{j>i}^{3}corr\left(s_i\dot{X}_i,s_j\dot{X}_j\right)/3\,,\tag{27}$$

$$\bar{\rho}_{B,X,WT}=\sum_{i=1}^{3}\sum_{j>i}^{3}corr\left(s_i\dot{X}_i,s_j\dot{X}_j\right)\cdot\left(\bar{s}_i+\bar{s}_j\right)/2\,,\tag{28}$$

where the subscripts *B*, *U*, and *WT* indicate a between-sector effect, unweighted correlation and weighted correlation, respectively. The subscript X is either value-added, employment, or labor productivity. Here, average

[24] As shown in Figure 15 and Table 11, the variances of growth contribution of the three sectors experience a decline. However, the covariance terms of the primary and secondary sectors increase significantly, whereas those of the tertiary and secondary term decrease drastically.

nominal value-added shares in the aggregate GDP ($\bar{s}_i$) are employed as weights for all variables.

[FIGURE 21 HERE]

The unweighted average correlations are almost identical to the weighted ones. Hence, we only plot the rolling weighted average correlations for the three variables in Figure 21. The average correlation for labor productivity shows a significant drop in the mid-1990s, with values declining from around 0.4 in the early 1990s to -0.40 in the early 2000s. Furthermore, the weighted correlations for value-added and employment demonstrate a much weaker declining trend in the mid-1990s compared with that for labor productivity. The results above suggest that the declining covariances between the sectoral labor productivity[25] mainly reflect the reduced correlation between sectors. In comparison, the decrease of covariances for value-added growth indicates the mixed results of the increasing stability of the underlying series and declining correlation, which is revealed partly by the disaggregate pairwise correlations in Figure 20.

The aggregate results of labor productivity decomposition shown in Figure 11 and Table 9 indicate that the covariances between employment and labor productivity growth have a small contribution (even in opposite direction) to the decline in aggregate volatility. However, the disaggregate results of sectoral labor productivity decomposition suggest that although the aggregate effects of covariances are trivial, the volatility contributions of both between-sector and within-sector covariances of employment and labor productivity are economically large, albeit with opposite signs (Figure 18 and Table 11). To further uncover the dynamics of correlations, we calculate the rolling average

[25] In the second sub-period, the covariances between weighted sectoral labor productivity growth decrease by 3.63 percentage points.

of within- and between-sector correlations of employment and labor productivity growth (Stiroh, 2009), using a rolling window of 5 years.

The average within-sector correlations of employment and labor productivity growth are estimated, following Equations 29 and 30. Both the unweighted and weighted correlations are calculated as follows:

$$\bar{\rho}_{W,U} = \sum_{i=1}^{3} corr\left(s_i\dot{L}_i, s_i\dot{v}_i\right)/3, \tag{29}$$

$$\bar{\rho}_{W,WT} = \sum_{i=1}^{3} corr\left(s_i\dot{L}_i, s_i\dot{v}_i\right)\cdot\bar{s}_i, \tag{30}$$

where the subscripts *W*, *U*, and *WT* indicate the within-sector effect, unweighted correlation and weighted correlation, respectively; $s_i\dot{L}_i$ and $s_i\dot{v}_i$ indicate employment growth and labor productivity growth for sector i weighted by its sectoral share, respectively; and $\bar{s}_i$ indicates the average sectoral share over the rolling window.

The average between-sector correlations of employment and labor productivity growth are calculated as Equations 31 and 32, in which the subscript B indicates between-sector effect:

$$\bar{\rho}_{B,U} = \sum_{i=1}^{3}\sum_{j\neq i}^{3} corr\left(s_i\dot{L}_i, s_j\dot{v}_j\right)/6, \tag{31}$$

$$\bar{\rho}_{B,WT} = \sum_{i=1}^{3}\sum_{j\neq i}^{3} corr\left(s_i\dot{L}_i, s_j\dot{v}_j\right)\cdot\left(\bar{s}_i + \bar{s}_j\right)/4. \tag{32}$$

[FIGURE 22 HERE]

We plot the rolling average of within- and between-sector correlations of employment and labor productivity in Figure 22. Both the weighted and unweighted correlations are shown. Figure 22 shows that the rolling within-sector correlations started to decline in the early 1990s, suggesting some remarkable changes of the link between employment and labor productivity growth. Interestingly, the average of between-sector correlations shows a modestly increasing trend. Furthermore, the significant drop of the within-sector covariances of employment and labor productivity growth mainly reflects a reduced correlation, whereas the increase of the between-sector covariances is driven by an increasing correlation since the variances of sectoral labor productivity growth experience a significant decline.

6.4 Sector Decomposition: More Sub-Sectors

The analysis in the previous section provides a brief view of the volatility decomposition from the sectoral production perspective. We incorporate a more disaggregate sectoral structure to study the sources of declining volatility of the Chinese economy.

As discussed in the previous section, the aggregate economy is the aggregation of the three main economic sectors, and the secondary and tertiary sectors can be further decomposed. At this point, the secondary sector is further decomposed into two sub-sectors, i.e., 1) industry and 2) construction. The tertiary sector is further decomposed into six sub-sectors, i.e., 1) transport, storage, and post, 2) wholesale and retail trades, 3) hotels and catering services, 4) financial intermediation, 5) real estate, and 6) other tertiary sub-sectors.

Without consistent employment data series for all the sub-sectors mentioned above, we only focus on the volatility decomposition in terms of sectoral value-added growth. The decomposition method is similar to that shown in Equations 22 and 23, in which the aggregate economic growth is the weighted sum of the sectoral value-added growth, and the weight is the two-period average nominal share of the sectoral value added in GDP. Furthermore, the covariances between sub-sectors of the same main economic sector are considered within effect of covariances, while those between sub-sectors of different main economic sectors are considered between effect of covariances.

We employ the data on the value-added of the 9 sub-sectors for the years 1978–2008 to conduct the similar analysis as that shown in the last section. Figures A4–A6 illustrate the growth contributions from the 9 sub-sectors. We can see that Figure A4 is nearly identical to Figure 14 in the last section, whereas Figures A5 and A6 provide a more detailed view of growth contributions. The 5-year rolling results of variance decomposition are plotted in Figures A7–A10.

[TABLE 12 HERE]

Table 12 compares the results of growth decomposition and variance decomposition for the two sub-periods. Almost all of the aggregate results (three main economic sectors) are similar to those in Table 11. For instance, there is no evidence of significant change for the aggregate economic growth, whereas the growth contributions of the three main economic sectors show different trends, i.e., an increase for the primary sector and a decrease for the other two sectors. Both the variances and covariances terms play an important role in the decline of aggregate volatility, and the variances dominate the decline in terms of magnitude (61.4%). The proportion attributed to the variances terms in Table 12 and Figure A7 is significantly smaller than that in Table 11 and Figure 16. This is because the variance of a main economic sector can be further decomposed into the variances of its sub-sectors and their covariances, which are basically positive according to Figures A9 and A10. Even in this case, the direct contributions of variances account for the major part of the aggregate volatility decline, confirming the conclusion in the previous section, that is, the decline in aggregate output volatility can be mainly traced to idiosyncratic shocks of individual sectors or shocks with heterogeneous effects on different sectors rather than common homogenous shocks across sectors. The variance of the secondary sector and the covariance between the secondary and tertiary sectors account for the major part of the total volatility decline (83.0% in total and 34.7% and 48.3%, respectively). Figures A4 and A7–A9 provide visible evidence of these results. We focus on some new findings when incorporating a more disaggregate sectoral structure.

First, the aggregate economic growth is dominated by the growth contribution of the sub-sector of industry, accounting for nearly 50% of the GDP growth over the last two decades. The growth contribution of the other tertiary sub-sector becomes increasingly important in the aggregate output growth, indicating a significant increase in the second sub-period.

Second, except for the other tertiary sub-sector, all sub-sectors experience a decline in the variances of their growth contributions, and the changes of five out of nine sub-sectors[26] are statistically significant. Furthermore, 30 out of 36 pairs of covariances between the growth contributions of sub-sectors show a decline,[27] while 20 pairs decrease significantly. These pairs of covariances with an increasing trend are concentrated in the relationship between the primary and secondary sectors, as well as in the relationship between financial intermediation and the secondary sectors.

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[26] These five sub-sectors are the primary sector, industry, construction, wholesale and retail trade, and real estate.

[27] The six pairs of covariances that experience an increase after 1992 include primary sector and industry, primary sector and construction, primary sector and real estate, industry and financial intermediation, construction and intermediation, as well as trade and financial intermediation.

Next, we calculate the weighted correlations within and between the three main economic sectors to rule out the effect of reduced variances. The lower left panel of Table 12 shows the average correlation coefficients. The between main sector correlations in Table 12 are qualitatively similar to those in Table 11, suggesting that the changes of pairwise covariances among the three main economic sectors reflect the change of their corresponding pairwise correlations. A new finding indicates that the decrease of covariances within the secondary sub-sectors is driven by the decrease of their variances rather than their correlations. However, the change of average correlation of all pairwise correlations between sub-sectors is not as drastic as that of the total covariances. This indicates that, on average, the significant decline in total covariances is primarily attributed to the reduced variances of all sub-sectors.

7 Sources: Demand Perspective

Another important disaggregate perspective in studying the sources of decline in output volatility is to investigate the decomposed components of the final demand side (Blanchard and Simon, 2001; Davis and Kahn, 2008). From a statistical accounting perspective, the GDP volatility depends on the variances of its components as well as on the covariances of the components, as well as their relative weights in GDP.

The aggregate output can be decomposed into several final demand components, namely, household consumption, government expenditure, investment, and net export. It is expressed as:

$$Y_t = \sum_{i=1}^{4} E_{i,t} = C_t + G_t + I_t + NE_t \,, \tag{33}$$

where Y, C, G, I, and NE indicate GDP, household consumption, government expenditure, investment and net exports, respectively. Each of these components is denoted by $E_{i,t}$.

The GDP growth can also be attributed to the contributions of its components. Given that both the level and growth rate of net exports often change sign, we construct the growth contribution of each component using a different approach instead of multiplying the relative share in GDP and the growth rate for each component.

First, all level values of GDP and its components are converted to be at constant price. Equation 34 states that the growth contribution of each component is defined as the ratio of the change in each component at time *t* to the aggregate GDP at time *t*-1. After the transformation, the growth contribution of each component is calculated as the product of the GDP growth and its growth contribution share, which is computed by dividing the change of its level by the change of the real GDP. This is expressed as:

$$\dot{Y}_t = \sum_{i=1}^{4} X_{i,t} = \sum_{i=1}^{4} \frac{\Delta E_{i,t}}{Y_{t-1}} = \sum_{i=1}^{4} \left(\frac{\Delta E_{i,t}}{\Delta Y_t} \cdot \frac{\Delta Y_t}{Y_{t-1}} \right) = \sum_{i=1}^{4} e_{i,t} \dot{Y}_t \,, \tag{34}$$

where $\dot{Y}_t$, $X_{i,t}$, and $e_{i,t}$ indicate GDP growth, growth contribution and growth contribution share of component *i* at time *t*, respectively.

Given the decomposition in terms of growth contributions, the aggregate volatility can be easily decomposed into the variances of all terms of growth contributions, and their covariances:

$$\operatorname{var}\left(\dot{Y}_t\right) = \sum_{i=1}^{4} \operatorname{var}\left(X_{i,t}\right) + \sum_{i=1}^{4} \sum_{j>i}^{4} 2\operatorname{cov}\left(X_{i,t}, X_{j,t}\right), \tag{35}$$

where $\dot{Y}_t$ and $X_{i,t}$ indicate the GDP growth and growth contribution of component i at time t, respectively.

We employ the data on GDP by expenditure approach for the years 1978–2008, including household consumption (HC), government consumption (GC), gross capital formation (GCF), and net exports (NE). Furthermore, household consumption can be divided into rural household consumption (RHC) and urban household consumption (UHC). The GCF can be divided into GFCF and changes of inventories. Table 13 compares the results of growth decomposition and variance decomposition for the two sub-periods.

[TABLE 13 HERE]

The growth contributions of the four expenditure terms are plotted in Figure 23. Growth contributions from both household consumption and investment play an important role in aggregate growth; in addition, investment shows a greater contribution than the other components after 2000. Government expenditure provides a relatively small and stable contribution to GDP growth. Remarkably, the growth contribution from trade (net exports) is volatile and presents counter-cyclical pattern before 2000.

We can see from the left panel of Table 13 that the growth contributions from both household consumption and government expenditure show a significant decline in the second sub-period, whereas that from GCF experiences a drastic increase. However, there is no evidence of significant change of growth contribution from net exports. These results suggest that although the GDP growth does not change significantly over the last three decades, its contributions from expenditure components vary greatly. The increasing importance of investment and decreasing contribution from consumption provide some evidence showing that China's economic growth is mainly driven by the investment, especially in the second period (Zheng, Bigsten and Hu, 2009). The findings here are also consistent with our previous finding that the capital growth in the second sub-period is significantly higher than that in the first one.

[FIGURE 23 HERE]

The volatility of household consumption experienced a sharp drop in the early 1990s, whereas that in the 1980s increased steadily. The significant decline is similar to that found in aggregate output volatility. The volatility of government expenditure shows a steady decline over the last three decades, despite a slight increase in the early 1990s. Although the government expenditure growth is remarkably volatile before the middle 1990s, with a rolling standard deviation greater than 5%, it only provides a small direct contribution to the aggregate volatility given its small and stable share (around 15% in the reform period). Investment is the most volatile component of GDP. Prior to the middle 1990s, the rolling standard deviation is greater than 8%, experiencing a significant increase in the early 2000s. Interestingly, the increase in the rolling standard deviation coincides with the period of overheating of the Chinese economy and the succeeding macro control policies. The increasing weight of investment in GDP as well as its significant volatility means that investment is the largest direct contributor to aggregate volatility. Despite a recent increase, the volatility of growth contribution from net exports also shows a drastic decline after the early 1990s, which may be attributed to the global economic crisis.

[FIGURE 24 HERE]

[FIGURE 25 HERE]

The rolling results of variance decomposition are plotted in Figures 24 and 25. The former illustrates the contributions from the variances and covariances of the expenditure terms, whereas the latter shows the aggregate direct contribution from variances and the aggregate contribution from covariances terms. Both figures present the same pattern, which shows that the declining volatility of GDP mostly reflects the significant drop of the direct contributions from variances of its demand components. The covariance terms, on the other hand, are more complicated, and show no clear trend if all the covariance terms are added up. The right panel of Table 13 compares the variance decomposition for the two sub-periods and provides more specific evidence.

In total, the variance terms account for 97.3% of the decline in output volatility, whereas the remaining part can be attributed to the covariance terms. All variance terms exhibit a decline after the early 1990s, albeit with different significance levels. In terms of magnitude, the variances of growth contribution from household consumption and investment account for most of the decline in output volatility (78.7%).

Only less than 3% of the volatility decline can be attributed to the total covariances, the terms of which vary notably. Meanwhile, the pairwise covariances of household consumption, government expenditure, and investment drop significantly in the second sub-period, whereas those of net exports between each of the other three components increase. Next, we separate the pairwise correlation coefficients of these terms into two groups: one including the correlations of growth contribution from net exports between each of the other three components, and the another covering pairwise correlations of these three components. The rolling results of correlation coefficients are illustrated in Figure 26. All correlations in the first group experience an increase after the early 1990s, except the correlation between investment and net exports, which shows a decline after the early 2000s. Correlations in the second group present a declining trend or at least a stable pattern in the second sub-period, despite a recent increase after the early 2000s. A potential explanation for the results stated above is that the growth contributions from local demands become less correlated along with the increasing integration with the global economy, whereas the growth contribution from net exports is becoming increasingly associated (or less negatively linked) with the local demands. Maybe a different mechanism is suggestive after China joins the WTO in 2003, since the trends of correlations have changed at that time. However, we do not have a clear perspective yet, given the limited time span after the WTO entry.

[FIGURE 26 HERE]

8 Sources: Regional Economic Perspective

When looking at Chinese provinces, we find that most of them have experienced a notable decline in output volatility. For instance, the standard deviation of the GDP growth of Beijing has decreased from 4.75% (for the years 1978–1992) to 1.56% (for the years 1993–2008), while that of Shanghai has decreased from 3.50% to 1.77%. Therefore, an interesting question emerges: "To what extent can we attribute the remarkable decline in China's output volatility to the declines in provincial volatility, as well as to the dynamics of correlations between provinces?"

Previous studies have provided some indirect answers to this question, which are somehow controversial. Xu (2002) and Xu and Voon (2003) find that there are significant co-movements among Chinese provinces. Moreover, they find that the national effects dominate in the dynamics of provincial business cycles despite the fact that coastal provinces follow the national business more closely, whereas the west regions are likely to be countercyclical. Nevertheless, Brun, Combes, and Renard (2002) examine the spillover effect between regions, and argue that the spillover from coastal areas to inland provinces is not sufficient to reduce the disparities in the short run. Trade barriers, price distortion, and rent seeking from local governments may be the potential contributors to this inefficient integration (Young, 2000). However, the arguments of Young (2000) are challenged by Holz (2009b), who reports a certain evidence of no increasing trade barriers and considers China as a relatively integrated large economy. Furthermore, Groenewold, Lee, and Chen (2007; 2008) employ a VAR model and find significant spillover effects from coastal provinces to central and western regions and from central region to western region. However, they find no spillover effects from western region to the two other regions.

If Young's (2000) conclusion is the case, an increasing trade barrier may result in a less integrated economy, suggesting that the decline in output volatility may reflect the decreasing correlations between provinces, apart from the declining variances of most provinces. In contrast, if Xu (2002) and Xu and Voon (2003) provide a picture that is closer to the fact, the correlation between provincial GDP growth is likely to increase or at least become stable over the last three decades. Moreover, the declining output volatility mainly stems from the increasing output stability of most provinces themselves.

Here, we employ the data on GDP and GDP growth for 31 provinces over the last three decades to investigate the sources of the decline in output volatility from the perspective of regional economy.

The aggregate GDP is the sum of the provincial GDP of 31 provinces in mainland China, and the national GDP growth is the weighted sum of the provincial GDP growth. The weight here is calculated as the two-year average nominal GDP share of each province:

$$\dot{Y}_t = \sum_{i=1}^{31} s_{i,t} \dot{P}_{i,t} , \tag{36}$$

where $\dot{Y}_t$, $\dot{P}_{i,t}$, and $s_{i,t}$ are the national GDP growth, GDP growth and the GDP share of province i at time t, respectively. Each term in Equation 36, $s_{i,t}\dot{P}_{i,t}$, is the provincial contribution to national output growth.

Using Equation 36, we can decompose the variance of the national GDP growth into the sum of variances of provincial growth contributions and the sum of pairwise covariances between provincial growth contributions. Moreover, we divide the Chinese provinces into three groups, namely, eastern, central and western regions, with 11, 8 and 12 provinces, respectively.[28] The sum of pairwise covariances can be further decomposed into the sum of covariances within regions and the sum of covariances between regions, as expressed in Equation 37:

[28] The eastern region covers 11 provinces, including Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, and Hainan. The central region covers 8 provinces, including Shanxi, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, and Hunan. The western region covers the rest 12 provinces, including Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang.

$$
\begin{aligned}
\operatorname{var}(\dot{Y}_t) &= \sum_{i=1}^{31}\operatorname{var}(s_{i,t}\dot{P}_{i,t}) + \sum_{i=1}^{31}\sum_{j>i}^{31} 2\operatorname{cov}(s_{i,t}\dot{P}_{i,t}, s_{j,t}\dot{P}_{j,t}) \\
&= \sum_{i=1}^{31}\operatorname{var}(s_{i,t}\dot{P}_{i,t}) + \sum_{K=1}^{3}\sum_{i=1}^{N_K}\sum_{j>i}^{N_K} 2\operatorname{cov}(s_{Ki,t}\dot{P}_{Ki,t}, s_{Kj,t}\dot{P}_{Kj,t}) \\
&\quad + \sum_{K=1}^{3}\sum_{L>K}^{3}\sum_{i=1}^{N_K}\sum_{j=1}^{N_L} 2\operatorname{cov}(s_{Ki,t}\dot{P}_{Ki,t}, s_{Lj,t}\dot{P}_{Lj,t}) \\
&= VAR + COV_{within} + COV_{between}
\end{aligned} \quad (37)
$$

where K, L, N_K, and N_L indicate the K^{th} group, L^{th} group, number of provinces in K^{th} group, and number of provinces in L^{th} group.

Figure 27 plots the growth contributions of the three groups, whereas Figures 28 illustrates the rolling results of variance decomposition with a window of 5 years in terms of provincial GDP growth contribution.

Similar to the analysis in the previous sections, we also compare the results of growth decomposition and variance decomposition for the two sub-periods. The left panel of Table 14 shows the results of growth decomposition, while the right panel compares the results of variance decomposition following Equation 37.

As shown in Figure 27, a remarkable discrepancy can be observed between the weighted sum of the provincial GDP growth and the national GDP growth as well as the sum between aggregate provincial nominal GDP and national nominal GDP after the early 1990s. These results have also been reported in Rawski (2001; 2002) and Holz (2003). These discrepancies may be attributed to several explanations. The first concerns the fact that the provinces over report nominal GDP and real GDP growth to satisfy their growth targets, and the NBS revises the aggregate provincial data when generating the national output data according to the sample surveys of NBS and estimations (Holz, 2003). The second argument states that the value-added of cross-province enterprises are reported repeatedly to different provinces so that the aggregation of provincial GDP is higher than the national value. Fortunately, these discrepancies seem systematically consistent for the years after the early 1990s, and the criticism of wide data falsification and dishonesty at provincial level lack strong evidence to back up such claims (Holz, 2003). Consequently, the provincial data on GDP and GDP growth are employed in this study without revisions despite the fact that the weighted sum of GDP growth is higher than the national value by 2 percent points.

[FIGURE 27 HERE]

Figure 27 and the left panel of Table 14 show that the eastern provinces contribute the most to the aggregate economic growth, with nearly 60% of the GDP growth of China coming from the contributions of the 11 coastal provinces. Compared with no significant change in average growth rate between the two sub-periods for national GDP growth as stated in previous sections, the weighted sum of the provincial GDP growth in the second sub-period is larger than that in the first sub-period by 2.25%, most of which can be attributed to growth contributions from the eastern provinces. As a result of the discrepancies between the national value and the sum of provincial values, we cannot conclude that either the eastern provinces grow faster or the average national GDP growth is higher after 1992.

The sum of variances of the provincial growth contribution can be considered the direct within effects, while the sum of the pairwise covariances presents the between effects. The results of variance decomposition in the right panel of Table 14 show that both the within and between effects contribute to the decline in the output volatility, but the latter dominates in terms of magnitude. Nearly 88.9% of the aggregate decline in volatility can be attributed to the decline in covariances terms. The direct within effects account only for the rest of the 11.1% of volatility decline. Figure 28 also indicates that between effects dominate the aggregate volatility for the last three decades, accounting for almost 90% of the total variances.

This result can be associated with the prevailing effects of common factors across provinces as well as the increasing economic integration and co-movement (Xu, 2002; Xu and Voon, 2003).The incremental and experimental reform since 1978 swept all the provinces in China. Although the reform has been initiated in the coastal provinces at the very beginning, the spillover effect plays an important role in subsequent economic integration (Groenewold, Lee and Chen, 2007; 2008).

[FIGURE 28]

[TABLE 14]

Most provinces experience a significant drop in volatility of GDP growth contribution after the early 1990s. Table 15 shows the comparisons of mean and variance of the growth contributions of the two sub-periods for 31 provinces. The left panel of Table 15 compares the mean growth rates, indicating that 21 out of 31 provinces show no significant change in the mean of growth contribution after 1992. Among 10 provinces that experience significant change in growth contribution in the second sub-period, 9 are eastern provinces. Considering the variance comparisons, we find that 30 out of 31 provinces show a decline in the volatility of growth contribution, and the declines in 24 provinces are statistically significant at least at the 10% significance level. Among the provinces, Jiangsu, Liaoning, Shandong, and Guangdong are the top 4 contributors to the decline in variances. As shown in Figure 29 and Table 14, the eastern provinces contribute the most to the direct within effects, accounting for 67.8% of the total decline in the variances of provincial growth contributions. The central provinces are the second biggest contributors, accounting for 26.4% of the total decline, whereas western provinces only account for the remaining 5.8%. The dominant role of eastern provinces is not only due to their increasingly stable GDP growth, but also due to their relatively large GDP share. The 11 eastern provinces account for more than 50% of the aggregate GDP, and this has increased steadily to nearly 60% in recent years.

Furthermore, we examine the raw GDP growth of all provinces rather than the growth contributions to rule out the effects of GDP shares. Table A7 shows the results of the mean and variance comparison of GDP growth for all provinces. All provinces show a decline in output volatility after 1992, with the declines in 26 provinces showing statistical significance.

[FIGURE 29 HERE]

[TABLE 15 HERE]

On the other hand, both the within- and between-group covariances of provincial growth contributions have contributed significantly to the decline in the aggregate output volatility. We plot all the within- and between-group rolling covariances in the left figures of Figure 30, 31, and 32. Both the within- and between-group covariances are substantial in terms of magnitude in the reform period, and co-move with each other notably. The right panel of Table 14 shows that the within- and between-group covariances account for 42.1% and 57.9% of the drop in total covariances, respectively.

In the investigation of the group-specific covariances, we find that the related terms in the eastern provinces dominate the total covariances and the decline of covariances as well as the decline in aggregate volatility. In the first place, among the three within-group covariances, those within the eastern provinces account for more than 80% of the total within-group covariances over the last three decades (see left side of Figure 31), and 78.5% of the decline in total within-group covariances (29.4% of aggregate decline in output volatility). The covariances within the central and within western provinces account for 15.5% and 6.0% of the decline in total within-group covariances, respectively. The left side of Figure 32 shows that the related covariances[29] of the eastern group are the major components of the total between-group covariances. Nearly 85% of both the level and the decline of the total between-group covariances are attributed to the terms, Cov-EC and Cov-EW, accounting for 43.3% of the decline in aggregate output vitality.

Remarkably, the significant drops in covariance terms may result from two kinds of factors, namely, the decreasing variances of individual provincial growth contribution and the decline in correlations between provinces. As a result, it is more interesting to look at the correlations rather than the covariances between provinces. We compute the average correlation coefficient between provinces using Equation 38, in which the weights served as the mean GDP shares of the corresponding provinces. To examine the differences in correlations within a group and between groups, we also calculate the within-group correlation coefficients following Equation 39 as well as the between-group ones following Equation 40. Finally, the average correlation coefficient within groups and that between groups are calculated following Equation 41 and 42 as shown below:

[29] Covariances related to the eastern provinces refer to the covariances between the eastern and central provinces (Cov-EC), and those between the eastern and western provinces (Cov-EW).

$$\bar{\rho} = \sum_{i=1}^{N} \sum_{j>i}^{N} corr\left(s_i \dot{P}_i, s_j \dot{P}_j\right) \cdot \left(\bar{s}_i + \bar{s}_j\right) / (N-1), \tag{38}$$

$$\bar{\rho}_{W,K} = \sum_{i=1}^{N_K} \sum_{j>i}^{N_K} corr\left(s_{Ki} \dot{P}_{Ki}, s_{Kj} \dot{P}_{Kj}\right) \cdot \left(\bar{s}_{Ki} + \bar{s}_{Kj}\right) / \left((N_K - 1) \sum_{i=1}^{N_K} \bar{s}_{Ki} \right), \tag{39}$$

$$\bar{\rho}_{B,K\cdot L} = \sum_{i=1}^{N_K} \sum_{j=1}^{N_L} corr\left(s_{Ki} \dot{P}_{Ki}, s_{Lj} \dot{P}_{Lj}\right) \cdot \left(\bar{s}_{Ki} + \bar{s}_{Lj}\right) / \left(N_L \sum_{i=1}^{N_K} \bar{s}_{Ki} + N_K \sum_{j=1}^{N_L} \bar{s}_{Lj} \right), \tag{40}$$

$$\bar{\rho}_W = \sum_{K=1}^{3} \sum_{i=1}^{N_K} \sum_{j>i}^{N_K} corr\left(s_{Ki} \dot{P}_{Ki}, s_{Kj} \dot{P}_{Kj}\right) \cdot \left(\bar{s}_{Ki} + \bar{s}_{Kj}\right) / (N-1), \tag{41}$$

$$\bar{\rho}_B = \sum_{K=1}^{3} \sum_{L>K}^{3} \sum_{i=1}^{N_K} \sum_{j=1}^{N_L} corr\left(s_{Ki} \dot{P}_{Ki}, s_{Lj} \dot{P}_{Lj}\right) \cdot \left(\bar{s}_{Ki} + \bar{s}_{Lj}\right) / \left(N - \sum_{K=1}^{3} \left(N_K \sum_{i=1}^{N_K} \bar{s}_{Ki} \right) \right), \tag{42}$$

where B and W indicate a between- and within-group correlations, respectively, and K and $K \cdot L$ indicate a correlation within group K and a correlation between group K and L, respectively.

Next, we plot the 5-year rolling correlation coefficients for within- and between-group terms in the right figures in Figures 30–32. The left bottom panel of Table 14 compares the average correlation coefficients for the two sub-periods.

Generally, rather than sharp decline in covariances, a slight increase is observed in the second sub-period for all correlation coefficients considered. Table 14 shows that the average correlation for all provinces increases from 0.44 to 0.55 after 1992. Among the six measures of within- and between-group correlations, the one within the eastern provinces and the one within the western provinces are the biggest and smallest in the two sub-periods, respectively. There are no significant differences among the six measures in terms of magnitude. However, the average within-group correlation is slightly greater than the between-group correlation in both sub-periods. These results provide some clues about the increasing economic integration in China. These indicate that the eastern provinces are more synchronized than those within the other two groups as well as provinces between each pair of three groups, on average. In addition, the slight increase found in all correlations suggests that the significant drop in covariances after 1992 mainly reflects the increasing stability of growth contributions for all individual provinces.

More specifically, the rolling results plotted in Figures 30–32 provide a dynamic view of the correlations within and between groups. As shown in Figure 30, the average correlations within groups and between groups move together over the last three decades. The correlations between provincial growth contributions show a drastic drop in the early 1990s. However, they experience a steep increase in the early 2000s and a sharp decline in recent years, which is quite different from the dynamics of corresponding covariances terms that are relatively stable after the early 1990s. The results suggest that the significant drop in covariance components in the early 1990s reflect both the effects of decreasing variances of all provinces as well as those of the declines in pairwise correlations. However, the stable covariances after the early 1990s mainly result from the less volatile provincial growth contributions rather than the correlations. In addition, the co-movements between provinces are overwhelming over the last three decades, despite two short periods with drastic declines in correlations. The correlations between provinces have increased steadily since 1978, indicating the occurrence of an increasing economic integration in the first half of the reform period (Xu, 2002; Xu and Voon, 2003). The common factors across provinces dominate economic growth and integration. The declines in correlations in the early 1990s and mid-2000s suggest that the provincial idiosyncratic factors play important roles and that the shocks at that time have heterogenous effects on different provinces.

Subsequently, we examine the group specific correlations shown in Figures 31 and 32. Most of the correlations present a similar pattern, in which the correlations increase steadily since the beginning of the reform period, decrease sharply in the early 1990s, rebound drastically in the early 2000s, and finally decrease significantly in subsequent years. This pattern confirms the conclusion we have made in the previous paragraph, that is, the significant decline in covariances in the early 1990s mainly due to a smaller correlation and the low covariances after 1993 can be attributed to low variances of provincial growth contributions. Meanwhile, attention must be given to some other results. First, among the three within-group correlations, the one within the eastern provinces is the biggest across the years, suggesting a closer within-group economic relationship. Figure 32 also illustrates that the between-group correlations are almost identical in the 2000s, while there are remarkable discrepancies between each pair of these in the 1980s and 1990s, especially in the late 1990s.

[FIGURE 30 HERE]

[FIGURE 31 HERE]

[FIGURE 32 HERE]

9 Conclusions

This essay intends to answer the following questions: "Has the economic growth of China become less volatile?" If this is the case, "What are the causes of the increasing stability of the Chinese economy?"

The answer to the first question is yes. After constructing the quarterly data on GDP growth over the last three decades, we identify the instability of quarterly GDP growth as well as the presence of one-time structural break in the variances of output growth. Further analyses reveal that the timing of structural shift or regime switching is likely to occur in the early 1990s statistically. Most emprical results suggest late 1992 or early 1993 as the break date, which could be slightly different when alternative model settings are considered. These findings are robust to the alternative measures of the GDP growth, namely, four-quarter, HP-filtered, and BP-filtered series. The findings are also robust to the alternative approaches of structural change or regime switching, including Nyblom-Hansen's L test (Nyblom, 1989; Hansen, 1992b), SupF tests for structural break (Andrews, 1993; Andrews and Ploberger, 1994; Andrews, 2003), and Markov Switching AR models (Hamilton, 1989; Kim and Nelson, 1999; McConnell and Perez-Quiros, 2000), among others. The results of this study suggest that the quarterly GDP growth of China experienced a one-time structural shift or regime switching from a state of higher variance to a state of lower variance in the years 1992–1993.

Nevertheless, the univariate analysis of China's GDP growth only provides a limited picture of the economic growth dynamics itself. Univariate analysis can only answer the questions as to whether the volatility of the GDP growth becomes less volatile and whether or not there is a structural change or regime shift in the process of economic growth. To uncover the sources of the decline in output volatility, we employ several decomposition approaches to examine the factors accounting for the increasing stability of the Chinese economy. The reform period is split into two sub-periods, namely, 1978-1992 and 1993–2008, according to the detected timing of structural break in this study. Subsequently, we compare the decomposition results for the two sub-periods and then plot the rolling results of the decomposed components.

First, we decompose the output volatility from the production perspective. At the aggregate level, our results indicate a sharp drop in the variances of employment and labor productivity except for their covariances. The decline in output volatility mainly results from the increasing stability of labor productivity in terms of magnitude. Further growth accounting analysis reveals that the less volatile TFP residual and the declining covariances between TFP and capital account for 68.7% and 30.8% of the decline in GDP volatility, respectively. This result is consistent with the conclusion of He, Chong, and Shi (2009), that is, TFP is the best explanatory factor of the aggregate business cycle. Significantly, the capital input growth is more volatile after 1992, although the difference between the two sub-periods is not statistically significant.

At the sectoral level, we decompose the aggregate volatility into the contributions from the sectoral variances of value-added growth and their covariances. We find that the growth contribution of the secondary sector is significantly pro-cyclical, whereas those of the primary and tertiary sectors are relatively stable despite the fact that the primary sector is increasingly becoming trivial. The value-added growth of all sectors becomes more stable. In addition, 77% of the decline in aggregate output volatility decline can be attributed to the direct contributions of the decreased sectoral variances, which is dominated by the decline in variances of the secondary sector in terms of magnitude. Therefore, the decline in aggregate output volatility can be mainly traced back to idiosyncratic shocks of individual sectors or shocks with different effects on different sectors, rather than common shocks across sectors those are found to be dominant in the increasing stability of the US economy (Stiroh, 2009). Moreover, in incorporating a more disaggregate sectoral structure with nine sub-sectors, we find similar results to those using the dataset of the three main economic sectors. Most sub-sectors show a significant decline in the volatility of value-added growth. Thus, the decline in aggregate output volatility mainly reflects the significant changes of sectoral variances.

Furthermore, labor productivity decomposition at the sectoral level shows that both the variances and covariances terms play important roles in the decline of aggregate volatility. The variances of sectoral labor productivity and their covariances between sectors account for most of the volatility decline (79.2%), which is consistent with the previous finding regarding the dominant role of labor productivity. Interestingly, although the aggregate covariances between employment and labor productivity contribute little to the aggregate volatility decline, the changes of decomposed within- and between-sector covariances are both economically large, albeit with opposite signs. The average within- and between-sector correlations between employment and labor productivity show a drastic decline trend and a modestly increasing trend, respectively. The opposite trends indicate that the increase of sectoral labor productivity is probably associated with the decrease of sectoral employment, whereas that is the decrease of one sector's employment is mainly transferred to other sectors.

Apart from the production perspective of volatility decomposition (Stiroh, 2009), the demand or expenditure side of GDP provides another important perspective of the sources of the declining output volatility (Blanchard and Simon, 2001; Davis and Kahn, 2008). Our analysis reveals that household consumption and investment contribute to the major part of the aggregate growth, although they show a significant decline and a significant increase after 1992, respectively. The increasing stability of all the demand components accounts for 97.3% of the decline in aggregate output volatility. In particular, consumption and investment account for 78.7% of the decline.

Only less than 3% of the decline in output volatility is explained by the total covariances among the final demand components. All pairwise correlations between net exports and each of the three other components show an increasing trend, whereas the pairwise correlations between any of the two of the local demands experience a decline or at least a stable pattern after the early 1990s. A potential explanation is that the growth contributions from local demand become less correlated along with the increasing integration with the global economy; meanwhile, the growth contribution from the net exports is becoming increasingly associated with local demands.

Finally, we incorporate the perspective of regional economy into our analysis. Over the last 30 years, 11 eastern provinces have contributed 60% to China's GDP growth. The decline in aggregate output volatility mainly reflects the decrease of covariances between provincial growth contributions. Only 11.1% of the decline is accounted for by the direct contributions from declining provincial volatility, suggesting that the decline in the covariances between provincial growth contributions plays a dominant role in the increasing stability of the Chinese economy. This result is consistent with the prevailing effects of the common factors across provinces as well as the increasing economic integration and co-movement (Xu, 2002; Xu and Voon, 2003).

Most provinces show a significant drop in the volatility of growth contribution and that of GDP growth after the early 1990s. On the other hand, the eastern provinces have contributed the most to the decline in the total variances. This dominant role of coastal provinces is due to their more stable GDP growth and increasing shares in the national GDP.

Both the within- and between-group covariances of provincial growth contributions have accounted for a significant part of the decline in the aggregate output volatility. Moreover, the covariances related to eastern provinces contribute more than 80% of both the level and decline of total covariances, thus accounting for the 72.7% of the decline in the aggregate output volatility. The analysis of weighted average correlation coefficient among the provincial growth contributions indicates that all of the within- and between-group correlations show a slight increase after 1992. This suggests that the drastic drop in the covariances mainly reflects the increasing stability of all individual provinces rather than the change in pairwise correlations.

There are two important remarks to note. First, our results, uncovered through different approaches (i.e., volatility decompositions from production perspective, demand perspective and regional economic perspective), are not exclusive but complementary to each other. Second, in the volatility decomposition of this study, we split the whole sample into two sub-periods using 1992 as the break year, which is suggested by the results of structural break detection. To test the robustness of our results, we also duplicate the same decomposition exercises using 1993 as the break year to split the whole sample into two sub-periods, namely, 1978–1993 and 1994 2008. Our results are robust to the different sample-splitting methods. For brevity, the results of volatility decomposition, using 1993 as break year, are not included in this essay, but can be provided upon request.

This study contributes to the existing literature on Chinese economy on several dimensions. First, studies on the Chinese business cycle and output volatility mainly focus on its characteristics, co-movement of output and inflation, synchronization among Chinese provinces, and underlying explanations of China's cyclical economic growth pattern. To our best knowledge, this is the first attempt to provide a rigorous analysis of the prominent phenomenon of increasing stability in China's economic growth by detecting the structural break in growth volatility as well as examining the sources of the volatility decline using several decomposition methods.

Second, aside from using several decomposition approaches already employed in existing studies about developed economies, such as the production perspective adopted by Stiroh (2009), we also incorporate several methods from several complementary perspectives, such as the volatility decomposition in terms of the demand components of GDP and from the regional economic perspective. In particular, investigations using the latter approach provide more abundant information in understanding the Chinese business cycles.

Third, investigations using volatility decomposition approaches from different perspectives could provide a comprehensive view about the volatility and business cycles of the Chinese economy. For instance, the co-movements of sectoral growth and regional growth show different features in terms of volatility dynamics. The idiosyncratic shocks to sectors play an important role so that the co-movement of sectoral growth is not as significant as that in the US. By contrast, Chinese provinces co-move to a large extent in the reform period, which is consistent with the existing findings about the dominant role of national common factors in the synchronization of Chinese regional economies.

Finally, the result of this essay regarding the existence of a structural break in the variance of GDP growth has important implications for future theoretical and empirical analyses of the Chinese economy. For instance, we should be more careful in conducting the calibration of a macroeconomic model, the estimation of a VAR model, and an OLS regression incorporating GDP growth over the period spanning the break time (most likely 1992–1993). This is because the underlying model assumptions may be invalid with the presence of a structural break or regime switch.

This study has some limitations, and there are some avenues for future research as well. First of all, given that the quarterly economic data of China are limited, we can only employ annual data to conduct volatility decomposition. Important information may be missed if high-frequency data are not used. For instance, China has experienced a sharp V-shape economic growth during the recent financial crisis, and the unprecedented investment package has played a crucial role in the economic rebound. However, this fact is not reflected by annual data. Nevertheless, using the annual data is the best way we can use in trying to uncover the sources of the volatility decline in China's economic growth. Second, provincial growth contributions are treated as random variables, while Chinese provinces are considered as independent entities in the volatility decomposition. In fact, Chinese provinces are all integrated into the Chinese economy, so that there would be strong spatial dependence in the growth contribution series of different provinces. How to incorporate the effect of spatial dependence into the analysis deserves more effort in the future research.

Moreover, using decomposition methods to investigate the sources of volatility decline is more or less an exercise of data mining about variance-covariance structure, although it provides insightful evidence for the sources of volatility decline. To associate the underlying explanations of Chinese cyclical growth pattern with the decline in output volatility (e.g., the role of SOE reform and other incremental reforms toward the market economy, the effect of macro-control policies, and so on), we should formulate several hypotheses and conduct a rigorous analysis to reveal the driving forces of China's economic growth volatility and decline. This issue is examined in the second essay of the author's PhD dissertation (Zhang, 2011b).

References

[1] Andrews, D. W. K. (1993). Tests for Parameter Instability and Structural Change with Unknown Change Point. *Econometrica* 61(4): 821-856.

[2] Andrews, D. W. K. (2003). Tests for Parameter Instability and Structural Change with Unknown Change Point: A Corrigendum. *Econometrica* 71(1): 395-397.

[3] Andrews, D. W. K. and Ploberger, W. (1994). Optimal Tests When a Nuisance Parameter Is Present Only under the Alternative. *Econometrica* 62(6): 1383-1414.

[4] Bai, C.-E., Hsieh, C.-T. and Qian, Y. (2006). The Return to Capital in China. *Brookings Papers on Economic Activity* 37(2006-2): 61-102.

[5] Bai, C.-E., Lu, J. and Tao, Z. (2006). The Multitask Theory of State Enterprise Reform: Empirical Evidence from China. *American Economic Review* 96(2): 353-353.

[6] Bai, C.-E., Lu, J., Tao, Z. and Wang, Y. (2000). A Multitask Theory of State Enterprise Reform. *Journal of Comparative Economics* 28(4): 716-738.

[7] Bai, J. and Perron, P. (1998). Estimating and Testing Linear Models with Multiple Structural Changes. *Econometrica* 66(1): 47-78.

[8] Baxter, M. and King, R. G. (1999). Measuring Business Cycles: Approximate Band-Pass Filters for Economic Time Series. *Review of Economics and Statistics* 81(4): 575-593.

[9] Blanchard, O. and Simon, J. (2001). The Long and Large Decline in US Output Volatility. *Brookings Papers on Economic Activity* 2001(1): 135-164.

[10] Bosworth, B. and Collins, S. M. (2008). Accounting for Growth: Comparing China and India. *Journal of Economic Perspectives* 22(1): 45-66.

[11] Brandt, L. and Zhu, X. (2000). Redistribution in a Decentralized Economy: Growth and Inflation in China under Reform. *Journal of Political Economy* 108(2): 422-439.

[12] Brandt, L. and Zhu, X. (2001). Soft Budget Constraint and Inflation Cycles: A Positive Model of the Macro-Dynamics in China during Transition. *Journal of Development Economics* 64(2): 437-457.

[13] Brandt, L. and Zhu, X. (2010). Accounting for China's Growth. *IZA Discussion Papers.*

[14] Brun, J. F., Combes, J. L. and Renard, M. F. (2002). Are there Spillover Effects between Coastal and Noncoastal Regions in China? *China Economic Review* 13(2-3): 161-169.

[15] Chari, V. V., Kehoe, P. J. and McGrattan, E. R. (2007). Business Cycle Accounting. *Econometrica* 75(3): 782-836.

[16] Chow, G. C. (1993). Capital Formation and Economic Growth in China. *Quarterly Journal of Economics* 108(3): 809-842.

[17] Chow, G. C. and Lin, A. (1971). Best Linear Unbiased Interpolation, Distribution, and Extrapolation of Time Series by Related Series. *Review of Economics and Statistics* 53(4): 372-375.

[18] Clements, M. P. and Krolzig, H.-M. (1998). A Comparison of the Forecast Performance of Markov-switching and Threshold Autoregressive Models of US GNP. *Econometrics Journal* 1(1): 47-75.

[19] Davis, S. J. and Kahn, J. A. (2008). Interpreting the Great Moderation: Changes in the Volatility of Economic Activity at the Macro and Micro Levels. *Journal of Economic Perspectives* 22(4): 155-180.

[20] Durland, J. M. and McCurdy, T. H. (1994). Duration-Dependent Transitions in a Markov Model of US GNP Growth. *Journal of Business and Economic Statistics* 12(3): 279-288.

[21] Filardo, A. J. (1994). Business-Cycle Phases and Their Transitional Dynamics. *Journal of Business and Economic Statistics* 12(3): 299-308.

[22] Galí, J. and Gambetti, L. (2009). On the Sources of the Great Moderation. *American Economic Journal: Macroeconomics* 1(1): 26-57.

[23] Gao, X. (2007). Business Cycle Accounting for the Chinese Economy. *MPRA Paper.*

[24] Gerlach-Kristen, P. (2009). Business Cycle and Inflation Synchronisation in Mainland China and Hong Kong. *International Review of Economics and Finance* 18(3): 404-418.

[25] Gong, G. and Lin, J. Y. (2008). Deflationary Expansion: An Overshooting Perspective to the Recent Business Cycle in China. *China Economic Review* 19(1): 1-17.

[26] Groenewold, N., Lee, G. and Chen, A. (2007). Regional Output Spillovers in China: Estimates from a VAR Model. *Papers in Regional Science* 86(1): 101-122.

[27] Groenewold, N., Lee, G. and Chen, A. (2008). Inter-regional Spillovers in China: The Importance of Common Shocks and the Definition of the Regions. *China Economic Review* 19(1): 32-52.

[28] Hamilton, J. D. (1989). A New Approach to the Economic Analysis of Nonstationary Time Series and the Business Cycle. *Econometrica* 57(2): 357-384.

[29] Hamilton, J. D. (1990). Analysis of Time Series Subject to Changes in Regime. *Journal of Econometrics* 45(1-2): 39-70.

[30] Hamilton, J. D. (1994). *Time Series Analysis.* Princeton, New Jersey, Princeton University Press.

[31] Hamilton, J. D. (1996). Specification Testing in Markov-switching Time-series Models. *Journal of Econometrics* 70(1): 127-157.

[32] Hamilton, J. D. and Susmel, R. (1994). Autoregressive Conditional Heteroskedasticity and Changes in Regime. *Journal of Econometrics* 64(1): 307-334.

[33] Hansen, B. E. (1992a). The Likelihood Ratio Test under Nonstandard Conditions: Testing the Markov Switching Model of GNP. *Journal of Applied Econometrics* 7(S): S61-82.

[34] Hansen, B. E. (1992b). Testing for Parameter Instability in Linear Models. *Journal of Policy Modeling* 14(4): 517-533.

[35] Hansen, B. E. (1997). Approximate Asymptotic p Values for Structural-Change Tests. *Journal of Business and Economic Statistics* 15(1): 60-67.

[36] He, Q., Chong, T.-L. T. and Shi, K. (2009). What Accounts for Chinese Business Cycle? *China Economic Review* 20(4): 650-661.

[37] Hess, G. D. and Iwata, S. (1997). Measuring and Comparing Business-Cycle Features. *Journal of Business and Economic Statistics* 15(4): 432-444.

[38] Ho, K. Y. and Tsui, A. K. C. (2004). Analysis of Real GDP Growth Rates of Greater China: An Asymmetric Conditional Volatility Approach. *China Economic Review* 15(4): 424-442.

[39] Hodrick, R. and Prescott, E. (1997). Post-war U.S. Business Cycles: An Empirical Investigation. *Journal of Money, Credit and Banking* 29(1): 1-16.

[40] Holz, C. A. (2003). "Fast, Clear and Accurate": How Reliable Are Chinese Output and Economic Growth Statistics? *China Quarterly* 173: 122-163.

[41] Holz, C. A. (2009a). *Measuring Chinese Productivity Growth, 1952-2007 (under revision)*, The MIT Press.

[42] Holz, C. A. (2009b). No Razor's Edge: Reexamining Alwyn Young's Evidence for Increasing Interprovincial Trade Barriers in China. *Review of Economics and Statistics* 91(3): 599-616.

[43] Hsieh, C.-T. and Klenow, P. J. (2009). Misallocation and Manufacturing TFP in China and India. *Quarterly Journal of Economics* 124(4): 1403-1448.

[44] Hsu, M. and Zhao, M. (2009). China's Business Cycles between 1954-2004: Productivity and Fiscal Policy Changes. *MPRA Paper*.

[45] Jorgenson, D. W. and Stiroh, K. J. (2000). Raising the Speed Limit: U.S. Economic Growth in the Information Age. *Brookings Papers on Economic Activity* 31(1): 125-236.

[46] Kim, C. J. and Nelson, C. R. (1999). Has the US Economy Become More Stable? A Bayesian Approach Based on A Markov-switching Model of the Business Cycle. *Review of Economics and Statistics* 81(4): 608-616.

[47] Lawley, D. N. (1963). On Testing A Set of Correlation Coefficients for Equality. *Annals of Mathematical Statistics* 34(1): 149-151.
[48] Lin, J. Y., Cai, F. and Li, Z. (1998). Competition, Policy Burdens, and State-Owned Enterprise Reform. *American Economic Review* 88(2): 422-427.
[49] Lin, J. Y. and Tan, G. (1999). Policy Burdens, Accountability, and the Soft Budget Constraint. *American Economic Review* 89(2): 426-431.
[50] McConnell, M. M. and Perez-Quiros, G. (2000). Output Fluctuations in the United States: What Has Changed Since the Early 1980's? *American Economic Review* 90(5): 1464-1476.
[51] Michael, B. (2004). Chinese Macroeconomic Stabilisation and Reform: A Briefing Note. *China and World Economy* 12(3): 61-69.
[52] Monsell, B. C. (2007). *Release notes for X-12-ARIMA Version 0.3*, Statistical Research Division, Census Bureau, U. S. Department of Commerce.
[53] Narayan, P. K., Narayan, S. and Smyth, R. (2009). Understanding the Inflation-Output Nexus for China. *China Economic Review* 20(1): 82-90.
[54] Naughton, B. J. (1995a). China's Macroeconomy in Transition. *China Quarterly*(144): 1083-1104.
[55] Naughton, B. J. (1995b). *Growing Out of the Plan: Chinese Economic Reform, 1978-1993*. New York, Cambridge University Press.
[56] Nyblom, J. (1989). Testing for the Constancy of Parameters over Time. *Journal of the American Statistical Association* 84(405): 223-230.
[57] Oppers, S. E. (1997). Macroeconomic Cycles in China *IMF Working Paper*.
[58] Perkins, D. H. (1988). Reforming China's Economic System. *Journal of Economic Literature* 26(2): 601-645.
[59] Poncet, S. and Barthelemy, J. (2008). China as An Integrated Area? *Journal of Economic Integration* 23(4): 896-926.
[60] Prasad, E. S. and Rajan, R. G. (2006). Modernizing China's Growth Paradigm. *American Economic Review* 96(2): 331-336.
[61] Qin, D. and Song, H. (2009). Sources of Investment Inefficiency: The Case of Fixed-Asset Investment in China. *Journal of Development Economics* 90(1): 94-105.
[62] Rajaguru, G. and Abeysinghe, T. (2004). Quarterly Real GDP Estimates for China and ASEAN4 with A Forecast Evaluation. *Journal of Forecasting* 23(6): 431-447.
[63] Ravn, M. O. and Uhlig, H. (2002). On Adjusting the Hodrick-Prescott Filter for the Frequency of Observations. *Review of Economics and Statistics* 84(2): 371-376.

[64] Rawski, T. G. (2001). What is Happening to China's GDP Statistics? *China Economic Review* 12(4): 347-354.

[65] Rawski, T. G. (2002). Measuring China's Recent GDP Growth: Where Do We Stand? *China Economic Quarterly* 2(1): 53-62.

[66] Stiroh, K. J. (2009). Volatility Accounting: A Production Perspective on Increased Economic Stability. *Journal of the European Economic Association* 7(4): 671-696.

[67] Stock, J. H. and Watson, M. W. (2002). Has the Business Cycle Changed and Why? *NBER Macroeconomics Annual* 17: 159-218.

[68] Stock, J. H. and Watson, M. W. (2005). Understanding Changes in International Business Cycle Dynamics. *Journal of the European Economic Association* 3(5): 968-1006.

[69] Tang, K. K. (1998). Economic Integration of the Chinese Provinces: A Business Cycle Approach. *Journal of Economic Integration* 13(4): 549-570.

[70] Wang, J.-m., Gao, T.-m. and McNown, R. (2009). Measuring Chinese Business Cycles with Dynamic Factor Models. *Journal of Asian Economics* 20(2): 89-97.

[71] Xu, X. (2002). Have the Chinese Provinces Become Integrated Under Reform? *China Economic Review* 13(2-3): 116-133.

[72] Xu, X. (2004). China's Gross Domestic Product Estimation. *China Economic Review* 15(3): 302-322.

[73] Xu, X. and Voon, J. P. (2003). Regional Integration in China: A Statistical Model. *Economics Letters* 79(1): 35-42.

[74] Young, A. (2000). The Razor's Edge: Distortions and Incremental Reform in the People's Republic of China. *Quarterly Journal of Economics* 115(4): 1091-1135.

[75] Young, A. (2003). Gold into Base Metals: Productivity Growth in the People's Republic of China During the Reform Period. *Journal of Political Economy* 111(6): 1220-1261.

[76] Yu, Q. (1997). Economic Fluctuation, Macro Control, and Monetary Policy in the Transitional Chinese Economy. *Journal of Comparative Economics* 25(2): 180-195.

[77] Yusuf, S. (1994). China's Macroeconomic Performance and Management During Transition. *Journal of Economic Perspectives* 8(2): 71-92.

[78] Zhang, J. (2008). Estimation of China's Provincial Capital Stock (1952-2004) with Applications. *Journal of Chinese Economic and Business Studies* 6(2): 177-196.

[79] Zhang, N. (2011). What Accounts for the Volatility of China's Economic Growth? *mimeo.* Department of Economics, Chinese University of Hong Kong.

[80] Zhang, Y. and Wan, G. (2005). China's Business Cycles: Perspectives from an AD–AS Model. *Asian Economic Journal* 19(4): 445-469.

[81] Zheng, J., Bigsten, A. and Hu, A. (2009). Can China's Growth be Sustained? A Productivity Perspective. *World Development* 37(4): 874-888.

Tables and Figures

Table 1 Simple Regression on the Time Trend of GDP Growth (FQ)

	(1) Level	(2) Level	(3) D1	(4) D1	(5) DM²	(6) DM²	(7) DM²
Time trend	0.00631	-0.000220	-0.000885	-0.000487	-0.136 ***	-0.0326	-0.0433 *
	(0.00772)	(0.00355)	(0.00363)	(0.00370)	(0.0351)	(0.0237)	(0.0234)
Constant	9.407 ***	1.137 **	0.0957	0.0618	18.40 ***	4.203 **	5.597 ***
	(0.583)	(0.470)	(0.275)	(0.282)	(2.648)	(2.005)	(1.998)
First lag		0.889 ***		0.0579		0.778 ***	0.995 ***
		(0.0410)		(0.0923)		(0.0572)	(0.0881)
Second lag							-0.281 ***
							(0.0881)
Observations	124	123	123	122	124	123	122
Adjusted R^2	-0.003	0.794	-0.008	-0.013	0.102	0.644	0.671

Note: Sample period covers 1979Q1 to 2009Q4. Level, D1, and DM² indicate level, first difference, and square of demeaned series of four-quarter GDP growth (FQ) respectively. ***, ** and * represent significance at 1%, 5% and 10% level respectively. Values in the parenthesis are standard error.

Table 2 L Test for Stability of GDP Growth

	GDP growth (FQ)		GDP growth (HP)		GDP growth (BP)	
	Estimate	L_c	Estimate	L_c	Estimate	L_c
A: Full sample (1978Q1-2009Q3)						
μ	1.12 (0.51)	0.05	-0.02 (0.08)	0.06	0.01 (0.06)	0.12
φ	0.89 (0.05)	0.03	0.90 (0.04)	0.04	0.96 (0.03)	0.07
σ^2	1.90 (0.44)	0.63 **	0.82 (0.15)	0.72 **	0.29 (0.06)	1.94 ***
Joint L_c	-	1.05 **	-	1.00 *	-	2.58 ***
R^2	0.80	-	0.81	-	0.92	-
B: First Period (1978Q1-1992Q4)						
μ	1.04 (0.66)	0.13	-0.07 (0.15)	0.13	0.00 (0.13)	0.26
φ	0.91 (0.07)	0.11	0.90 (0.05)	0.04	0.96 (0.04)	0.17
σ^2	3.29 (0.97)	0.14	1.29 (0.29)	0.18	0.60 (0.11)	0.33
Joint L_c	-	0.40	-	0.40	-	0.73
R^2	0.79	-	0.83	-	0.92	-
C: Second Period (1993Q1-2009Q3)						
μ	1.38 (0.56)	0.14	0.03 (0.08)	0.22	-0.00 (0.02)	0.35
φ	0.86 (0.05)	0.12	0.82 (0.07)	0.08	0.97 (0.02)	0.27
σ^2	0.76 (0.12)	0.49 **	0.39 (0.08)	0.05	0.03 (0.01)	0.17
Joint L_c	-	0.67	-	0.31	-	0.82
R^2	0.79	-	0.66	-	0.95	-

Note: Sample period covers 1979Q1 to 2009Q4. FQ, HP and BP represent four-quarter GDP growth, HP filtered GDP sereis, and BP filtered series respectively. Values in the parenthesis are standard error. ***, ** and * represent significance at 1%, 5% and 10% level respectively. Critical values for the null hypothesis of no break for individual parameter at 1%, 5% and 10% level are 0.75, 0.47 and 0.35 respectively. Critical values for the null hypothesis of joint stability for all three parameters at 1%, 5% and 10% level are 1.35, 1.01 and 0.85 respectively.

Table 3 Tests for Structural Break of GDP Growth: Full Sample

	GDP growth (FQ)			GDP growth (HP)			GDP growth (BP)		
Null	Sup	Exp	Ave	Sup	Exp	Ave	Sup	Exp	Ave
A: Variance									
$\sigma_1^2 = \sigma_2^2$	7.34	2.43	3.11	9.16	3.31	3.75	28.72	12.16	13.99
	(0.10)	(0.02)	(0.03)	(0.05)	(0.01)	(0.02)	(0.00)	(0.00)	(0.00)
Estimated Break		1993Q1			1992Q2			1993Q2	
B: Others									
$\mu_1 = \mu_2$	1.92	0.16	0.23	4.62	0.37	0.38	3.93	0.40	0.48
	(0.86)	(0.92)	(0.94)	(0.34)	(0.59)	(0.79)	(0.45)	(0.56)	(0.69)
Estimated Break		None			None			None	
$\phi_1 = \phi_2$	3.59	0.27	0.30	4.27	0.54	0.69	5.09	0.47	0.43
	(0.51)	(0.72)	(0.87)	(0.39)	(0.43)	(0.52)	(0.28)	(0.49)	(0.74)
Estimated Break		None			None			None	
$\mu_1 = \mu_2, \phi_1 = \phi_2$	4.66	0.57	0.67	8.43	1.16	1.16	75.22	33.18	2.21
	(0.69)	(0.84)	(0.96)	(0.21)	(0.47)	(0.73)	(0.00)	(0.54)	(0.33)
Estimated Break		None			None			(1983Q4)	

Note: Sample period covers 1979Q1 to 2009Q4. FQ, HP and BP represent four-quarter GDP growth, HP filtered GDP sereis, and BP filtered GDP series respectively. Sup, Exp, and Ave represent the statistic $supF_n$, $expF_n$, and $aveF_n$, respectively. Values in the parenthesis are asymptotical p-values.

Table 4 Tests for Structural Break in Variance of GDP Growth: Subsamples

	GDP growth (FQ)			GDP growth (HP)			GDP growth (BP)		
Null	Sup	Exp	Ave	Sup	Exp	Ave	Sup	Exp	Ave
A: First Period	*1979Q1-1992Q4*			*1978Q1-1992Q1*			*1981Q1-1993Q1*		
$\sigma_1^2 = \sigma_2^2$	6.49	1.35	1.51	5.31	1.29	1.55	5.61	1.58	2.11
	(0.16)	(0.12)	(0.19)	(0.26)	(0.13)	(0.18)	(0.23)	(0.10)	(0.10)
Estimated Break	None			None			None		
B: Second Period	*1993Q1-2009Q4*			*1992Q2-2009Q4*			*1993Q2-2006Q4*		
$\sigma_1^2 = \sigma_2^2$	3.71	1.02	1.44	1.83	0.16	0.23	2.38	0.42	0.57
	(0.48)	(0.20)	(0.20)	(0.89)	(0.91)	(0.93)	(0.76)	(0.53)	(0.61)
Estimated Break	None			None			None		

Note: FQ, HP and BP represent four-quarter GDP growth, HP filtered GDP sereis, and BP filtered GDP series respectively. Sup, Exp, and Ave represent the statistic $\sup F_n$, $\exp F_n$, and $\mathrm{ave}F_n$, respectively. Values in the parenthesis are asymptotical p-values.

Table 5 Tests for Structural Break in Variance of GDP Growth: AR Models

	GDP growth (FQ)			GDP growth (HP)			GDP growth (BP)		
Null	Sup	Exp	Ave	Sup	Exp	Ave	Sup	Exp	Ave
A: AR(1)									
$\sigma_1^2 = \sigma_2^2$	7.34	2.43	3.11	9.16	3.31	3.75	28.72	12.16	13.99
	(0.10)	(0.02)	(0.03)	(0.05)	(0.01)	(0.02)	(0.00)	(0.00)	(0.00)
Estimated Break		1993Q1			1992Q2			1993Q2	
B: AR(2)									
$\sigma_1^2 = \sigma_2^2$	7.46	2.55	3.37	9.34	3.26	3.84	35.45	15.96	21.27
	(0.10)	(0.03)	(0.03)	(0.04)	(0.01)	(0.02)	(0.00)	(0.00)	(0.00)
Estimated Break		1993Q3			1992Q2			2001Q2	
C: AR(3)									
$\sigma_1^2 = \sigma_2^2$	7.01	2.50	3.41	8.31	2.78	3.38	25.49	10.82	14.87
	(0.12)	(0.03)	(0.03)	(0.07)	(0.02)	(0.03)	(0.00)	(0.00)	(0.00)
Estimated Break		1993Q1			1992Q2			2002Q2	

Note: Sample period covers 1979Q1 to 2009Q4. FQ, HP and BP represent four-quarter GDP growth, HP filtered GDP sereis, and BP filtered GDP series respectively. Sup, Exp, and Ave represent the statistic $supF_n$, $expF_n$, and $aveF_n$, respectively. Values in the parenthesis are asymptotical p-values.

Table 6 Parameter Estimates and Related Tests for Markov Switching Model (FQ)

	AR(1)	MSH-1		MSIH	
		Regime 1	Regime 2	Regime 1	Regime 2
A:Model Estimation					
δ or μ	1.12 **	1.17 **		1.34 **	1.14 **
	(0.53)	(0.52)		(0.53)	(0.54)
φ	0.89 ***	0.88 ***		0.88 ***	
	(0.05)	(0.05)		(0.05)	
σ	1.38	1.90 ***	0.90 ***	1.90 ***	0.90 ***
	(0.16)	(0.38)	(0.13)	(0.37)	(0.10)
Log Likelihood	-213.87	-202.03		-201.84	
SIC	-221.09	-216.47		-218.69	
AIC	-218.59	-211.46		-212.84	
HQIC	-216.87	-208.03		-208.84	
B: Residual Diagnostic					
Ljung-Box $Q_1(8)$	28.19***	19.75 ***		19.81 ***	
Ljung-Box $Q_2(8)$	16.82**	13.26 *		11.46	
Skewness	-0.91***	-0.32		-0.41	
Kurtosis	7.49***	3.23		3.36	
Jarque-Bera	120.47***	2.41		4.19	
C: Instability Tests (Nyblom-Hansen L test)					
Joint	1.05 **	0.66		0.80	
δ or μ	0.05	0.06		0.05	0.08
φ	0.03	0.04		0.04	
σ^2	0.63 **	0.03	0.17	0.04	0.20
D: Transition Probability					
P(R1|-)	-	0.972	0.015	0.972	0.015
P(R2|-)	-	0.028	0.985	0.028	0.985
E: Regime Classification					
Quarters	79Q2-09Q4	81Q1-92Q4	79Q2-79Q4 93Q1-09Q4	81Q1-92Q4	79Q2-79Q4 93Q1-09Q4
Length	123	48	75	48	75

Note: Sample period covers 1979Q1 to 2009Q4. FQ indicates the series is four-quarter GDP growth. Ljung-Box $Q_1(8)$ and $Q_2(8)$ indicate Liung-Box Q statistics for autocorrelations with 8 lags for standardized residuals and squared standardized residuals respectively. Jarque-Bera is Jarque-Bear statistic for normal distribution of residual. Values in the parenthesis are standard error. ***, ** and * represent significance at 1%, 5% and 10% level respectively.

Table 7 Parameter Estimates and Related Tests for Markov Switching Model (BP)

	AR(1)	MSIH-1		MSIH	
		Regime 1	Regime 2	Regime 1	Regime 2
A: Model Estimation					
δ or μ	0.01	-0.01		0.03	-0.01
	(0.06)	(0.03)		(0.13)	(0.03)
φ	0.96 ***	0.98 ***		0.98 ***	
	(0.03)	(0.03)		(0.03)	
σ	0.54	0.78 ***	0.17 ***	0.78 ***	0.17 ***
	(0.05)	(0.08)	(0.03)	(0.09)	(0.02)
Log Likelihood	-82.59	-43.71		-43.64	
SIC	-89.54	-57.61		-59.86	
AIC	-87.79	-52.91		-54.37	
HQIC	-85.59	-49.71		-50.64	
B: Residual Diagnostic					
Ljung-Box $Q_1(8)$	152.01 ***	93.59 ***		93.96 ***	
Ljung-Box $Q_2(8)$	97.75 ***	47.13 ***		47.34 ***	
Skewness	-0.74	-0.31		-0.39	
Kurtosis	4.76	2.37		2.41	
Jarque-Bera	22.54 ***	3.37		4.20	
C: Instability Tests (Nyblom-Hansen L test)					
Joint	2.58 ***	1.02		1.11	
δ or μ	0.12	0.16		0.12	0.14
φ	0.07	0.05		0.05	
σ^2	1.94 ***	0.16	0.05	0.16	0.05
D: Transition Probability					
P(R1|-)	-	0.975	0.028	0.973	0.031
P(R2|-)	-	0.025	0.972	0.027	0.969
E: Regime Classification					
Quarters	81Q2-06Q4	81Q2-90Q4 91Q2-93Q1 06Q4	91Q1 93Q2-06Q3	81Q2-90Q3 91Q3-93Q1 06Q4	90Q4-91Q2 93Q2-06Q3
Length	103	48	55	46	57

Note: Sample period covers 1981Q1 to 2006Q4. BP indicates that the series is Band-Pass filtered GDP. Ljung-Box $Q_1(8)$ and $Q_2(8)$ indicate Liung-Box Q statistics for autocorrelations with 8 lags for standardized residuals and squared standardized residuals respectively. Jarque-Bera represents Jarque-Bear statistic for normal distribution of residual. Values in the parenthesis are standard error. ***, ** and * represent significance at 1%, 5% and 10% level respectively.

Table 8 Parameter Estimates and Related Tests for Markov Switching Model (AR(3))

	AR(3)	MSIH-1		MSIH	
		Regime 1	Regime 2	Regime 1	Regime 2
A: Four-Quarter GDP Growth					
δ or μ	1.49 ***	1.50 ***		1.32 *	1.47 ***
	(0.43)	(0.39)		(0.71)	(0.39)
φ1	0.97 ***	1.00 ***		1.01 ***	
	(0.09)	(0.10)		(0.10)	
φ2	0.13	0.08		0.07	
	(0.12)	(0.13)		(0.13)	
φ3	-0.25 ***	-0.23 ***		-0.22 **	
	(0.09)	(0.09)		(0.09)	
σ	1.34	2.04 ***	0.96 ***	2.15 **	0.98 ***
		(-)	(-)	(1.38)	(0.43)
Log Likelihood	-206.63	-195.86		-195.59	
Jarque-Bera	104.07 ***			87.07 ***	
P(R1|-)	-	0.944	0.018	0.948	0.012
P(R2|-)	-	0.056	0.982	0.052	0.988
Quarters	79Q4-09Q4	83Q3-90Q2	79Q4-83Q2 90Q3-09Q4	84Q1-90Q1	79Q4-83Q4 90Q2-09Q4
Length	121	32	89	29	92
B: Band-Pass Filtered GDP					
δ or μ	0.00052	0.0077		-0.02	0.01
	(0.013)	(0.01)		(0.03)	(0.01)
φ1	2.55 ***	2.50 ***		2.50 ***	
	(0.06)	(0.07)		(0.06)	
φ2	-2.32 ***	-2.24 ***		-2.25 ***	
	(0.12)	(0.12)		(0.12)	
φ3	0.76 ***	0.73 ***		0.73 ***	
	(0.06)	(0.06)		(0.06)	
σ	0.13	0.19 ***	0.07 ***	0.19 ***	0.08 ***
		()	()	(0.09)	(0.03)
Log Likelihood	60.58	76.98		76.54	
Jarque-Bera	2.88			1.68	
P(R1|-)	-	0.977	0.001	0.987	0.010
P(R2|-)	-	0.023	0.999	0.013	0.990
Quarters	81Q4-06Q4	81Q4-92Q1	92Q2-06Q4	81Q4-92Q1	92Q2-06Q4
Length	101	42	59	42	59

Note: Jarque-Bera represents Jarque-Bear statistic for normal distribution of residual. Values in the parenthesis are standard error. ***, ** and * represent significance at 1%, 5% and 10% level respectively.

Table 9 Growth and Variance Decomposition: Labor Productivity

	Growth Decomposition				Variance Decomposition		
	1978-1992	1993-2008	Change		1978-1992	1993-2008	Change
GDP	8.98	9.67	0.69	Var(GDP)	10.75	3.01	-7.73 **
Labor	2.45	0.99	-1.46 ***	Var(Labor)	0.56	0.04	-0.52 ***
ALP	6.52	8.68	2.16 **	Var(ALP)	10.80	3.31	-7.49 **
				2Cov(L,ALP)	-0.61	-0.33	0.28 ***
				Corr(L,ALP)	-0.12	-0.47 *	-0.35

Note: Growth Decomposition shows the breakdown of economic growth into employment (Labor) growth and average labor productivity (ALP) growth. Significance levels of growth change are from a T-test of the null hypothesis of equal mean with unequal variance for the two sub-periods. Variance Decomposition shows the breakdown of variance of economic growth into the variance of Labor growth, variance of ALP growth and twice of their covariance. Significance levels of variance change are from Levene's robust test for the equality of variances for the two sub-periods. Significance levels of covariance change are from a two-sample test for the null of equal covariances for the two sub-periods. Significance levels of correlation coefficient change are from a two-sample test for the null of equal correlation coefficient for the two sub-periods (Lawley, 1963). ***, ** and * represent significance at 1%, 5% and 10% level respectively.

Table 10 Growth and Variance Decomposition: Growth Accounting

	Growth Decomposition				Variance Decomposition		
	1978-1992	1993-2008	Change		1978-1992	1993-2008	Change
GDP	8.98	9.67	0.69	Var(GDP)	10.75	3.01	-7.73 **
Labor	1.29	0.48	-0.81 ***	Var(Labor)	0.16	0.01	-0.15 ***
Capital	4.08	6.17	2.09 ***	Var(Capital)	0.66	1.10	0.44
TFP	3.61	3.09	-0.52	Var(TFP)	7.52	2.21	-5.31 **
	Correlation Comparison			*SumVar*	*8.34*	*3.32*	*-5.02*
Corr(L,K)	0.19	-0.82 ***	-1.01 ***	2Cov(L,K)	0.12	-0.20	-0.32 ***
Corr(L,TFP)	-0.07	-0.09	-0.02	2Cov(L,TFP)	-0.15	-0.03	0.12 ***
Corr(K,TFP)	0.55 **	0.02	-0.53 *	2Cov(K,TFP)	2.43	0.05	-2.38 *
				SumCov	*2.40*	*-0.18*	*-2.58*

Note: Growth Decomposition shows the breakdown of economic growth into employment (Labor, L) growth, capital stock (Capital, K) growth and total factor productivity (TFP) growth. Significance levels of growth change are from a T-test of the null hypothesis of equal mean with unequal variance for the two sub-periods. Variance Decomposition shows the breakdown of variance of economic growth into the variance of Labor growth, variance of Capital growth, variance of TFP growth and twice of their pairwise covariances. Significance levels of variance change are from Levene's robust test for the equality of variances for the two sub-periods. Significance levels of covariance change are from a two-sample test for the null of equal covariances for the two sub-periods. Significance levels of correlation coefficient change are from a two-sample test for the null of equal correlation coefficient for the two sub-periods (Lawley, 1963). ***, ** and * represent significance at 1%, 5% and 10% level respectively.

Table 11 Growth and Variance Decomposition: Sectoral Growth

	Growth Decomposition				Variance Decomposition		
	1978-1992	1993-2008	Change		1978-1992	1993-2008	Change
Sectoral Output Decomposition							
Sum(GC)	8.85	9.62	0.77	Var(Sum(GC))	10.37	3.01	-7.36 **
S1	1.52	0.62	-0.89 **	Var(S1)	1.50	0.05	-1.45 ***
S2	4.50	5.26	0.76	Var(S2)	5.11	1.91	-3.20 **
S3	2.83	3.73	0.90 **	Var(S3)	1.40	0.35	-1.05 ***
	Correlation Comparison			*Sum Var*	*8.02*	*2.31*	*-5.70*
Corr(S1,S2)	-0.32	0.52 **	0.84 **	2Cov(S1,S2)	-1.79	0.32	2.11 ***
Corr(S1,S3)	0.14	-0.40	-0.53	2Cov(S1,S3)	0.39	-0.10	-0.50 ***
Corr(S2,S3)	0.70 ***	0.30	-0.41	2Cov(S2,S3)	3.75	0.49	-3.27 *
				SumCov	*2.35*	*0.70*	*-1.66*
Sectoral Labor Productivity Decomposition							
Sum(GC)	8.85	9.62	0.77	Var(GC)	10.37	3.01	-7.36 **
Sum(L)	3.68	2.47	-1.21	Sum(Var(L))	2.41	2.65	0.24
Sum(ALP)	5.17	7.15	1.98	Sum(Var(ALP))	6.79	3.17	-3.63
				Sum(2Cov(L))	0.39	-0.82	-1.20
				Sum(2Cov(ALP))	0.12	-2.08	-2.20
				Sum(Cov-W/I)	-1.19	-3.51	-2.32
				Sum(Cov-B/N)	1.85	3.60	1.75

Note: Sectoral Output Decomposition shows the decomposition results in terms of growth contributions (GC) of sectoral value-added growth. Sectoral Labor Productivity Decomposition shows the decomposition results in terms of growth contributions of sectoral employment (L) growth and labor productivity (ALP) growth. S1, S2 and S3 represent the growth contributions of primary, secondary and tertiary sectors. Cov-W/I and Cov-B/N represent covariances terms within sector and between sectors. Significance levels of growth change are from a T-test of the null hypothesis of equal mean with unequal variance for the two sub-periods. Significance levels of variance change are from Levene's robust test for the equality of variances for the two sub-periods. Significance levels of covariance change are from a two-sample test for the null of equal covariances for the two sub-periods. Significance levels of correlation coefficient change are from a two-sample test for the null of equal correlation coefficient for the two sub-periods (Lawley, 1963). ***, ** and * represent significance at 1%, 5% and 10% level respectively.

Table 12 Growth and Variance Decomposition: Extended Sectoral Growth

	Growth Decomposition				Variance Decomposition		
	1978-1992	1993-2008	Change		1978-1992	1993-2008	Change
Sum(GC)	8.97	9.59	0.61		10.68	3.02	-7.66 **
S1	1.49	0.62	-0.87 **	Var(S1)	1.40	0.05	-1.36 ***
S21	4.21	4.70	0.49	Var(S21)	3.96	1.43	-2.53 **
S22	0.42	0.53	0.11	Var(S22)	0.18	0.05	-0.13 **
S31	0.45	0.56	0.11 *	Var(S31)	0.03	0.01	-0.02
S32	0.61	0.71	0.10	Var(S32)	0.60	0.03	-0.57 ***
S33	0.19	0.23	0.04	Var(S33)	0.02	0.01	-0.01
S34	0.45	0.43	-0.02	Var(S34)	0.12	0.09	-0.04
S35	0.37	0.34	-0.04	Var(S35)	0.10	0.03	-0.07 *
S36	0.78	1.46	0.68 ***	Var(S36)	0.10	0.11	0.01
Sum(S1)	1.49	0.62	-0.87	Sum(Var(S1))	1.40	0.05	-1.36
Sum(S2)	4.63	5.23	0.60	Sum(Var(S2))	4.14	1.48	-2.66
Sum(S3)	2.85	3.73	0.88	Sum(Var(S3))	0.96	0.28	-0.69
	Correlation Comparison			*SumVar*	6.51	1.81	-4.70
Corr(S1,S1)	-	-	-	Cov(S1,S1)	-	-	-
Corr(S2,S2)	0.59	0.83	0.24	Cov(S2,S2)	0.99	0.43	-0.55
Corr(S3,S3)	0.20	0.06	-0.14	Cov(S3,S3)	0.54	0.10	-0.45
Corr(S1,S2)	-0.30	0.49	0.79	Cov(S1,S2)	-1.77	0.31	2.08
Corr(S1,S3)	0.07	-0.17	-0.25	Cov(S1,S3)	0.23	-0.12	-0.35
Corr(S2,S3)	0.40	0.19	-0.21	Cov(S2,S3)	4.18	0.48	-3.70
Corr-W/I	0.30	0.22	-0.08	Cov-W/I	1.53	0.53	-1.00
Corr-B/N	0.18	0.14	-0.04	Cov-B/N	2.64	0.68	-1.96
Corr	0.21	0.17	-0.04	*SumCov*	4.18	1.21	-2.96

Note: S1, S21, S22, S31, S32, S33, S34, S35 and S36 represent the growth contributions of primary sector (S1), industry (S21), construction (S22), transport, storage and post (S31), wholesale and retail trades (S32), hotels and catering services (S33), financial intermediation (S34), real estate (S35), and other tertiary sub-sectors (S36). Cov(Si,Si) and Corr(Si,Si) represent the total covariances and average correlation within the main economic sector i, for i=1,2,3. Cov(Si,Sj) and Corr(Si,Sj) represent the total covariances and average correlation between the main economic sector i and j, for i=1,2, j=2,3 and i<j. Cov-W/I, Cov-B/N, Corr-W/I and Corr-B/N represent total covariances within sector and between sectors and average correlations within sector and between sectors. Corr represents the average pairwise correlation between growth contributions of sub-sectors. Here, the weight for computing the average correlation is the average nominal sectoral share in GDP over a sub-period. Significance levels of growth change are from a T-test of the null hypothesis of equal mean with unequal variance for the two sub-periods. Significance levels of variance change are from Levene's robust test for the equality of variances for the two sub-periods. Significance levels of covariance change are from a two-sample test for the null of equal covariances for the two sub-periods. Significance levels of correlation coefficient change are from a two-sample test for the null of equal correlation coefficient for the two sub-periods (Lawley, 1963). ***, ** and * represent significance at 1%, 5% and 10% level respectively.

Table 13 Growth and Variance Decomposition: Final Demands

	Growth Decomposition				Variance Decomposition		
	1978-1992	1993-2008	Change		1978-1992	1993-2008	Change
GDP	8.98	9.67	0.69	Var(GDP)	10.75	3.01	-7.73 **
HC	4.33	3.23	-1.09 *	Var(HC)	3.77	1.04	-2.73 *
GC	1.77	1.29	-0.48 *	Var(GC)	0.73	0.09	-0.64 ***
GCF	2.79	4.45	1.67 *	Var(GCF)	6.56	3.22	-3.35
NE	0.09	0.69	0.60	Var(NE)	3.53	2.73	-0.80
	Correlation Comparison			*SumVar*	*14.59*	*7.07*	*-7.52*
Corr(HC,GC)	0.29	0.65 ***	0.36	2Cov(HC,GC)	0.97	0.40	-0.56 ***
Corr(HC,GCF)	0.80 ***	0.02	-0.78 **	2Cov(HC,GCF)	7.96	0.07	-7.89 **
Corr(HC,NE)	-0.73 ***	-0.67 ***	0.06	2Cov(HC,NE)	-5.31	-2.26	3.05
Corr(GC,GCF)	0.31	-0.20	-0.52	2Cov(GC,GCF)	1.38	-0.22	-1.59 ***
Corr(GC,NE)	-0.32	-0.42	-0.10	2Cov(GC,NE)	-1.03	-0.42	0.61 ***
Corr(GCF,NE)	-0.81 ***	-0.28	0.54 **	2Cov(GCF,NE)	-7.81	-1.63	6.17
				SumCov	*-3.85*	*-4.06*	*-0.21*

Note: HC, GC, GCF and NE represent the growth contributions of household consumption, government consumption, gross capital formation, and net exports. Significance levels of growth change are from a T-test of the null hypothesis of equal mean with unequal variance for the two sub-periods. Significance levels of variance change are from Levene's robust test for the equality of variances for the two sub-periods. Significance levels of covariance change are from a two-sample test for the null of equal covariances for the two sub-periods. Significance levels of correlation coefficient change are from a two-sample test for the null of equal correlation coefficient for the two sub-periods (Lawley, 1963). ***, ** and * represent significance at 1%, 5% and 10% level respectively.

Table 14 Growth and Variance Decomposition: Regional Growth

	Growth Decomposition				Variance Decomposition		
	1978-1992	1993-2008	Change		1978-1992	1993-2008	Change
Sum(All)	9.91	12.17	2.25	Var(All)	12.32	4.36	-7.96
Sum(East)	5.53	7.46	1.93	Sum(Var(E))	0.93	0.33	-0.59
Sum(Center)	2.56	2.73	0.17	Sum(Var(C))	0.27	0.04	-0.23
Sum(West)	1.83	1.98	0.15	Sum(Var(W))	0.08	0.03	-0.05
	Correlation Comparison			*Sum Var*	*1.28*	*0.41*	*-0.87*
Corr(E,E)	0.55	0.65	0.09	Cov(E,E)	3.99	1.65	-2.34
Corr(C,C)	0.39	0.57	0.18	Cov(C,C)	0.61	0.15	-0.46
Corr(W,W)	0.38	0.49	0.11	Cov(W,W)	0.27	0.08	-0.18
Corr(E,C)	0.42	0.51	0.09	Cov(E,C)	3.02	0.99	-2.03
Corr(E,W)	0.43	0.55	0.11	Cov(E,W)	2.23	0.81	-1.42
Corr(C,W)	0.39	0.51	0.12	Cov(C,W)	0.92	0.27	-0.65
Corr-W/I	0.48	0.60	0.12	Cov-W/I	4.87	1.88	-2.98
Corr-B/N	0.42	0.52	0.11	Cov-B/N	6.17	2.07	-4.10
Corr	*0.44*	*0.55*	*0.11*	*SumCov*	*11.04*	*3.95*	*-7.08*

Note: East (E), Center (C) and West (W) represent growth contributions of eastern, central and western group. Cov(i,i) and Corr(i,i) represent the total covariances and average correlation within the group i, for i=E,C,W. Cov(i,j) and Corr(i,j) represent the total covariances and average correlation between group i and j, i and j correspond to each pair of group E, C and W. Cov-W/I, Cov-B/N, Corr-W/I and Corr-B/N represent total covariances within group and between groups, and average correlations within group and between groups. Corr represents the average pairwise correlation between growth contributions of 31 provinces. Here, the weight for computing the average correlation is the average nominal provincial share in national GDP over a sub-period.

Table 15 Mean and Variance Comparisons of Growth Contribution for All Provinces

	Mean Comparison			Variance Comparison		
	1978-1992	1993-2008	Change	1978-1992	1993-2008	Change
Beijing	0.28	0.36	0.08 *	0.021	0.006	-0.015
Tianjin	0.16	0.23	0.07 **	0.008	0.002	-0.006 *
Hebei	0.44	0.61	0.17 **	0.046	0.013	-0.033 ***
Shanxi	0.21	0.23	0.02	0.023	0.003	-0.021 ***
InnerMongolia	0.17	0.25	0.08	0.008	0.012	0.005 *
Liaoning	0.51	0.50	-0.01	0.111	0.015	-0.096 ***
Jilin	0.22	0.22	0.00	0.025	0.002	-0.023 ***
Heilongjiang	0.29	0.31	0.01	0.013	0.001	-0.012 ***
Shanghai	0.44	0.56	0.12 **	0.036	0.005	-0.030 ***
Jiangsu	0.91	1.19	0.28 *	0.242	0.056	-0.186 *
Zhejiang	0.59	0.86	0.27 ***	0.092	0.037	-0.056
Anhui	0.33	0.35	0.02	0.050	0.007	-0.043 ***
Fujian	0.30	0.47	0.17 ***	0.019	0.012	-0.007
Jiangxi	0.23	0.22	-0.00	0.010	0.003	-0.008 ***
Shandong	0.84	1.16	0.32 **	0.142	0.061	-0.081 *
Henan	0.52	0.62	0.10	0.085	0.018	-0.067 **
Hubei	0.43	0.40	-0.03	0.054	0.006	-0.048 ***
Hunan	0.33	0.38	0.05	0.011	0.003	-0.007 **
Guangdong	0.99	1.46	0.47 ***	0.204	0.125	-0.080 *
Guangxi	0.19	0.26	0.07 *	0.012	0.006	-0.005
Hainan	0.07	0.06	-0.01	0.004	0.001	-0.003
Chongqing	0.16	0.19	0.03	0.004	0.001	-0.002
Sichuan	0.43	0.44	0.01	0.026	0.006	-0.020 ***
Guizhou	0.13	0.10	-0.03	0.005	0.000	-0.004 ***
Yunnan	0.20	0.20	0.00	0.007	0.002	-0.005 ***
Tibet	0.01	0.02	0.00	0.000	0.000	-0.000 ***
Shaanxi	0.20	0.22	0.01	0.013	0.002	-0.011 ***
Gansu	0.12	0.11	-0.01	0.008	0.000	-0.008 ***
Qinghai	0.02	0.03	0.00	0.001	0.000	-0.001 ***
Ningxia	0.03	0.03	0.00	0.000	0.000	-0.000 ***
Xinjiang	0.15	0.13	-0.02	0.002	0.001	-0.001 ***
Sum	*9.91*	*12.17*	*2.25*	*12.32*	*4.36*	*-7.96*

Note: The provinces' names represent the growth contributions of each province. Significance levels of growth change are from a T-test of the null hypothesis of equal mean with unequal variance for the two sub-periods. Significance levels of variance change are from Levene's robust test for the equality of variances for the two sub-periods. ***, ** and * represent significance at 1%, 5% and 10% level respectively.

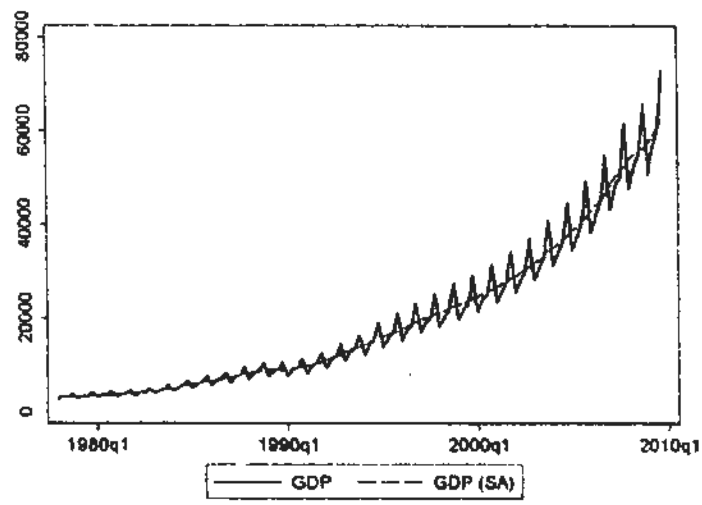

Figure 1 Unadjusted and Seasonally Adjusted Quarterly Real GDP
Note: Sample period covers 1979Q1 to 2009Q4. SA indicates that the searies is seasonally adjusted.

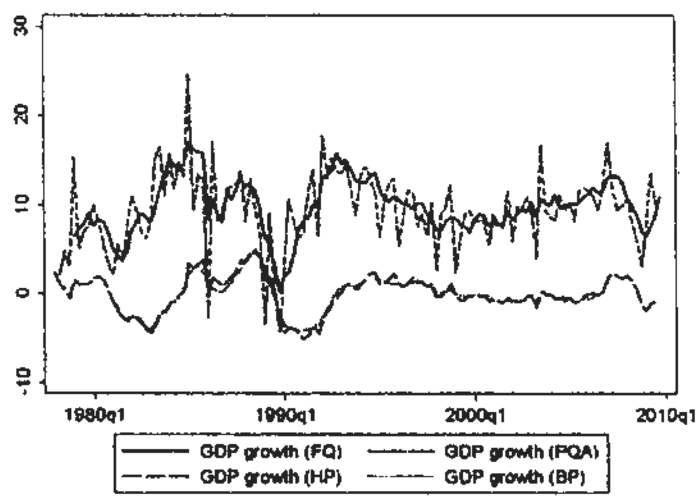

Figure 2 Unadjusted and Seasonally Adjusted Quarterly Real GDP Growth
Note: Sample period covers 1979Q1 to 2009Q4. FQ, PQA, HP and BP represent four-quarter GDP growth (year-over-year), annulized quarter-over-quarter quarterly GDP grwoth, HP filtered GDP and BP filtered GDP, respectively. These four series above are all based on seasonally adjusted quarterly GDP.

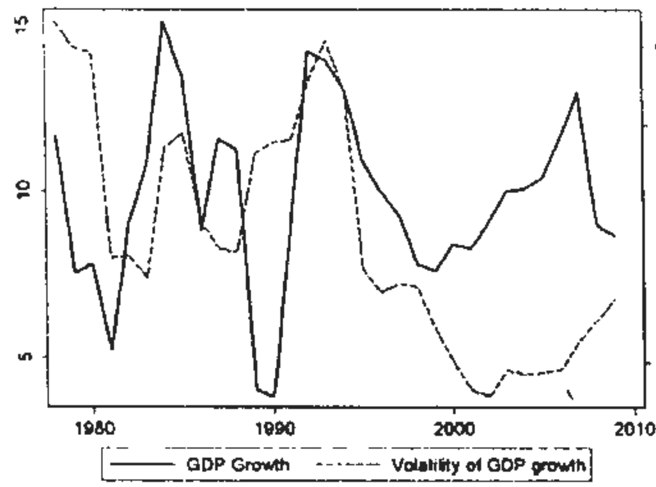

Figure 3 GDP Growth and Rolling Volatility: Annual

Note: Sample period covers 1978 to 209. GDP growth and Volatility of GDP Growth correspond to left scale and right scale, respectively.

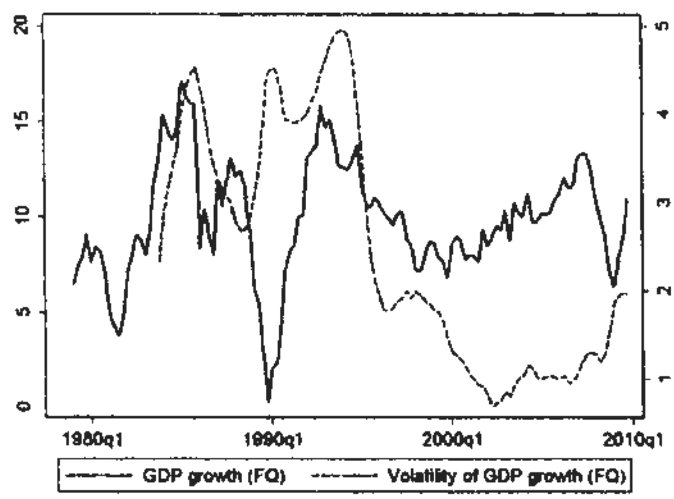

Figure 4 GDP Growth and Rolling Volatility: Quarterly

Note: Sample period covers 1979Q1 to 2009Q4. FQ indicates the series is four-quarter GDP growth. GDP growth and volatility of GDP growth correspond to left scale and right scale, respectively.

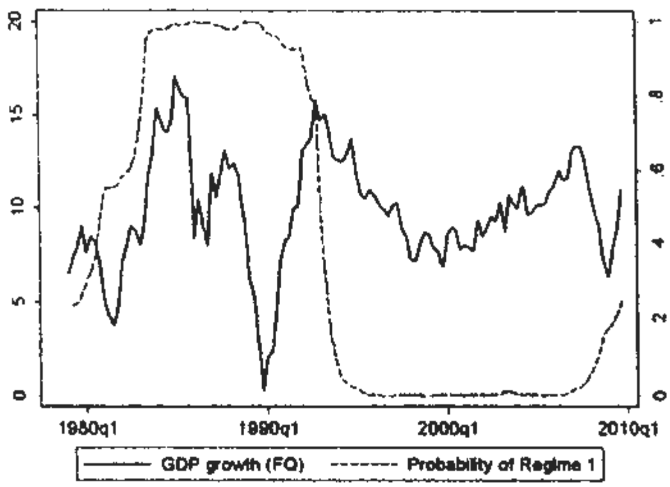

Figure 5 Smoothed Probability of Regime 1 (FQ, MSH Model with 1 Lag)
Note: Sample period covers 1979Q1 to 2009Q4. FQ indicates the series is four-quarter GDP growth. MSH model indicates the Markov Swithcing model with state-dependent variance. GDP growth and probability of Regime 1 correspond to left scale and right scale, respectively. Probability of Regime 1 represents the smoothed probability of the high-variance state.

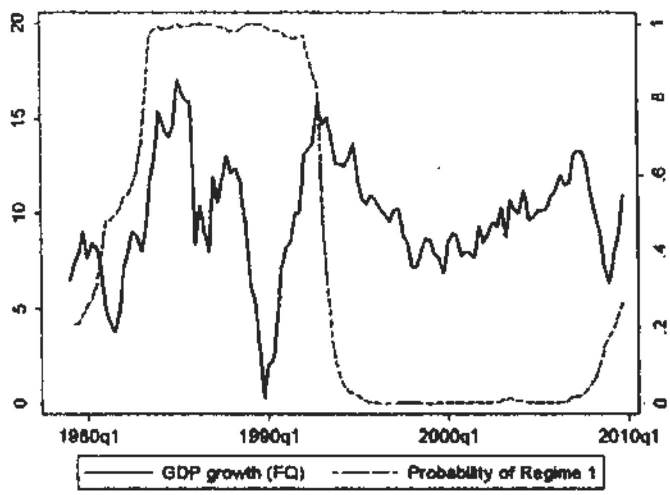

Figure 6 Smoothed Probability of Regime 1 (FQ, MSIH Model with 1 Lag)
Note: Sample period covers 1979Q1 to 2009Q4. FQ indicates the series is four-quarter GDP growth. MSIH model indicates the Markov Swithcing model with state-dependent constan and variance. GDP growth and probability of Regime 1 correspond to left scale and right scale, respectively. Probability of Regime 1 represents the smoothed probability of the high-variance state.

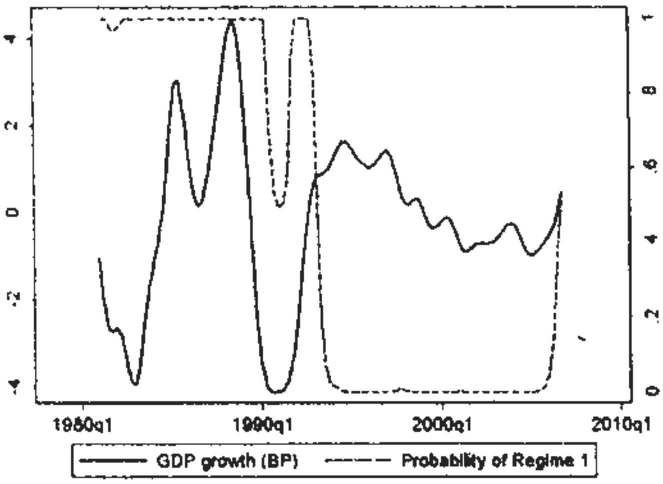

Figure 7 Smoothed Probability of Regime 1 (BP, MSH Model with 1 Lag)
Note: Sample period covers 1981Q1 to 2006Q4. BP indicates the series is Band-Pass filtered GDP. MSH model indicate the Markov Swithcing model with state-dependent variance. GDP growth and probability of Regime 1 corresponds to left scale and right scale, respectively. Probability of Regime 1 represent smoothed probability of the high-variance state.

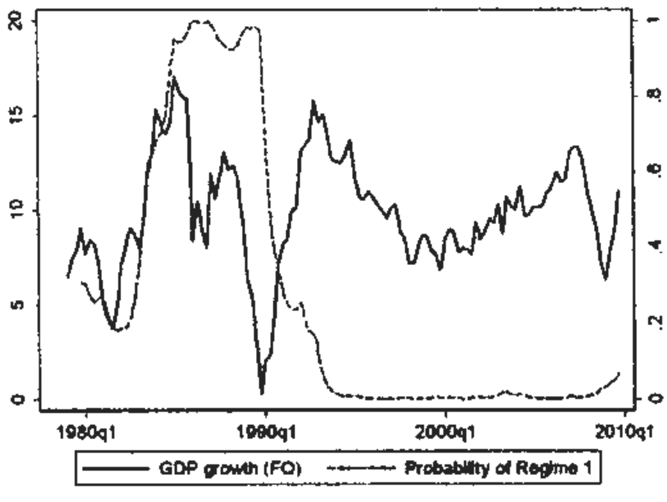

Figure 8 Smoothed Probability of Regime 1 (FQ, MSIH Model with 3 Lags)
Note: Sample period covers 1979Q1 to 2009Q4. FQ indicates the series is four-quarter GDP growth. MSIH model indicates the Markov Swithcing model with state-dependent constan and variance. GDP growth and probability of Regime 1 correspond to left scale and right scale, respectively. Probability of Regime 1 represents the smoothed probability of the high-variance state.

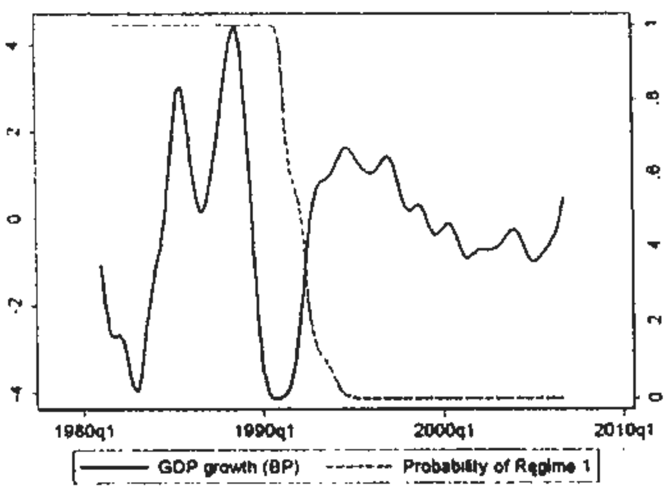

Figure 9 Smoothed Probability of Regime 1 (BP, MSH Model with 3 Lags)
Note: Sample period covers 1981Q1 to 2006Q4. BP indicates the series is Band-Pass filtered GDP. MSH model indicates the Markov Swithcing model with state-dependent variance. GDP growth and probability of Regime 1 correspond to left scale and right scale, respectively. Probability of Regime 1 represents smoothed probability of the high-variance state.

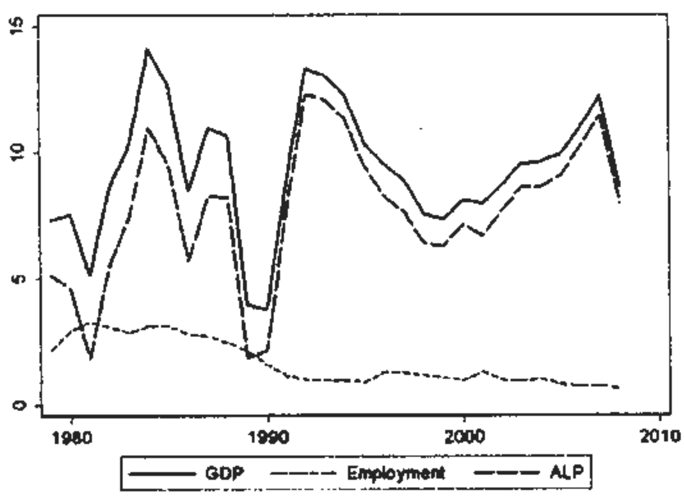

Figure 10 Growth Decomposition of Labor Productivity
Note: Sample period covers 1978 to 2008. GDP, Employment and ALP represent the growth rates of GDP, employment, and labor productivity, respectively.

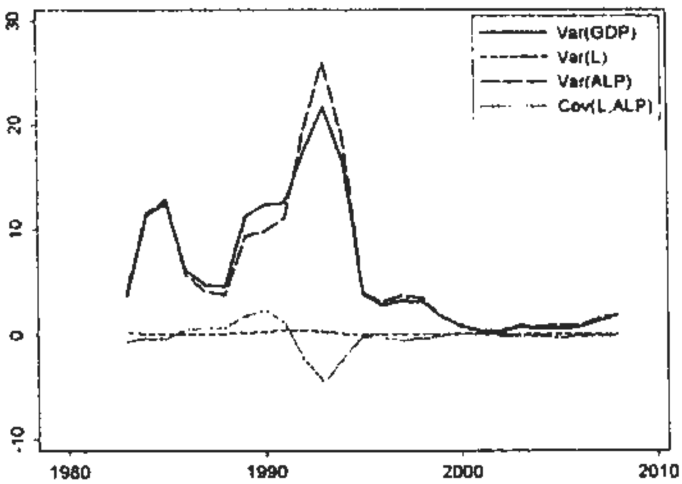

Figure 11 Rolling Variance Decomposition: Labor Productivity

Note: Sample period covers 1978 to 2008. GDP, L and ALP represent the growth rates of GDP, employment, and labor productivity, respectively. The rolling variance decomposition is calculated using a window of 5 years.

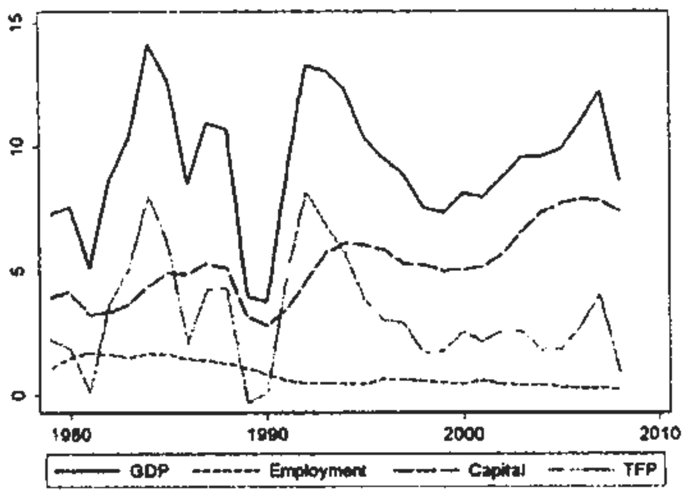

Figure 12 Growth Decomposition: Growth Accounting

Note: Sample period covers 1978 to 2008. GDP, Employment, Capital and TFP represent GDP growth, growth contributions of employment, capital, and total factor productivity, respectively.

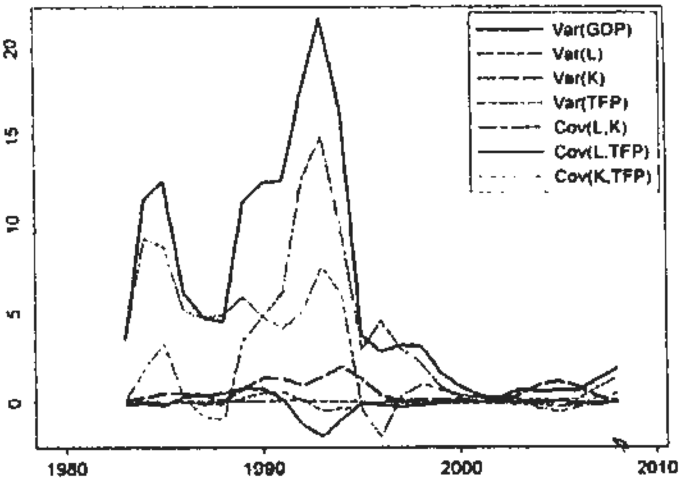

Figure 13 Rolling Variance Decomposition: Growth Accounting

Note: Sample period covers 1978 to 2008. GDP, L, K and TFP represent GDP growth, growth contributions of employment, capital, and total factor productivity, respectively. The rolling variance decomposition is calculated using a window of 5 years.

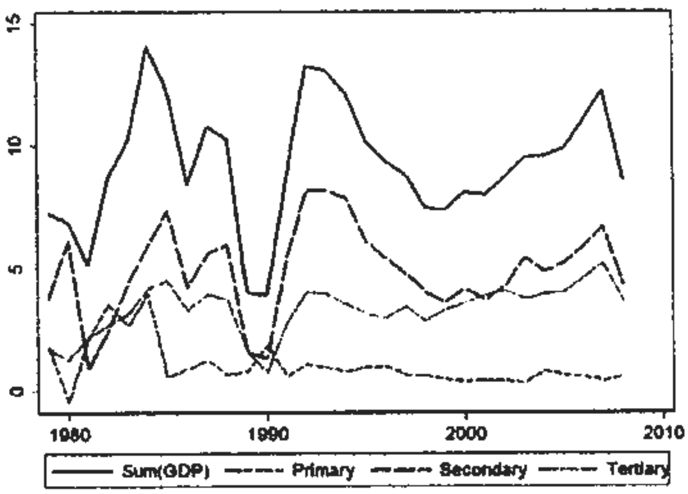

Figure 14 Growth Decomposition: Three Sectors

Note: Sample period covers 1978 to 2008. Sum(GDP), Primary, Secondary and Tertiary represent the sum of sectoral growth contributions, growth contributions of the primary, secondary and tertiary sector, respectively.

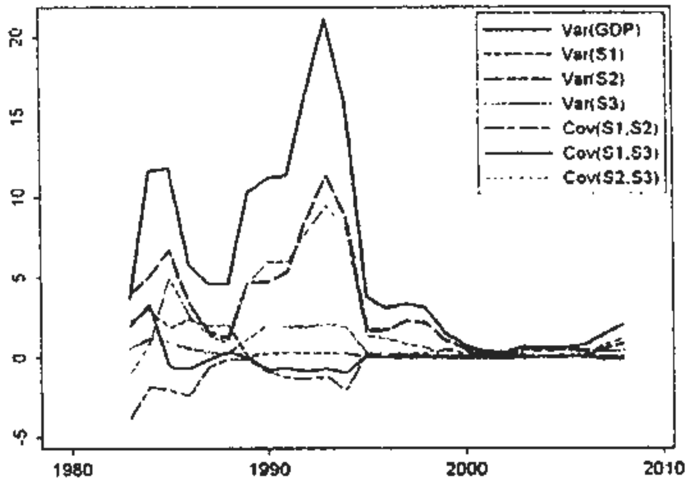

Figure 15 Rolling Variance Decomposition: Three Sectors

Note: Sample period covers 1978 to 2008. GDP, S1, S2 and S3 represent the sum of sectoral growth contributions, growth contributions of the primary, secondary and tertiary sector, respectively. The rolling variance decomposition is calculated using a window of 5 years.

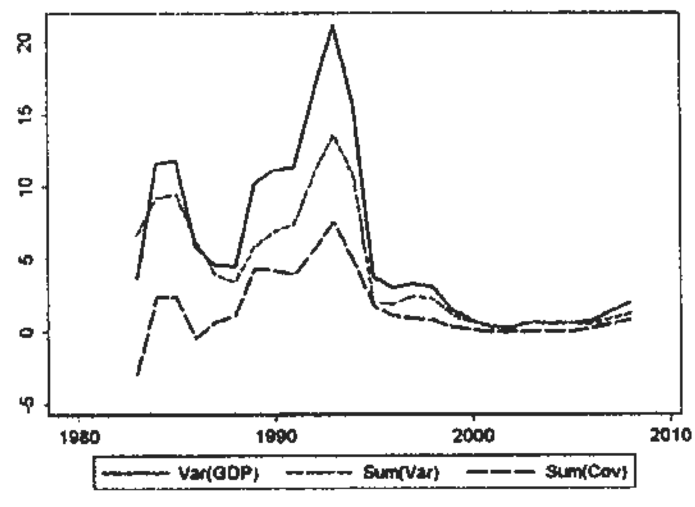

Figure 16 Rolling Variance Decomposition: Three Sectors (Sum)

Note: Sample period covers 1978 to 2008. GDP represents the sum of sectoral growth contributions. Sum(Var) and Sum(Cov) represent the sum of variances of sectoral growth contributions and the sum of covariances between sectoral growth contributions, respectively. The rolling variance decomposition is calculated using a window of 5 years.

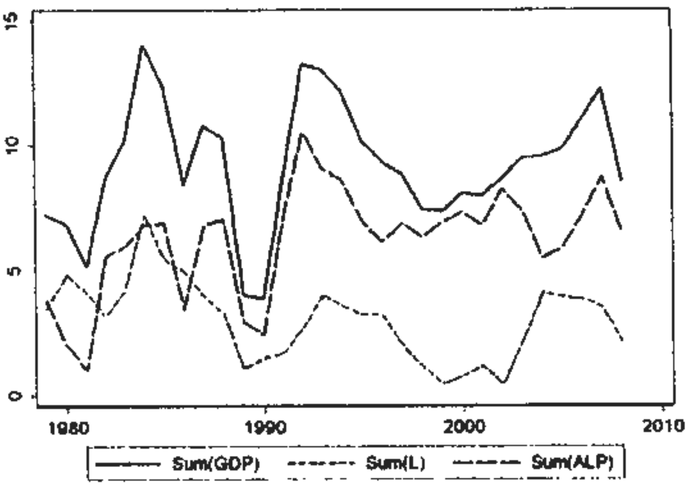

Figure 17 Growth Decomposition: Sectoral Labor Productivity

Note: Sample period covers 1978 to 2008. Sum(GDP), Sum(L) and Sum(ALP) represent the sum of sectoral growth contributions, the sum of growth contributions of sectoral employment, and the sum of growth contributions of sectoral labor productivity, respectively.

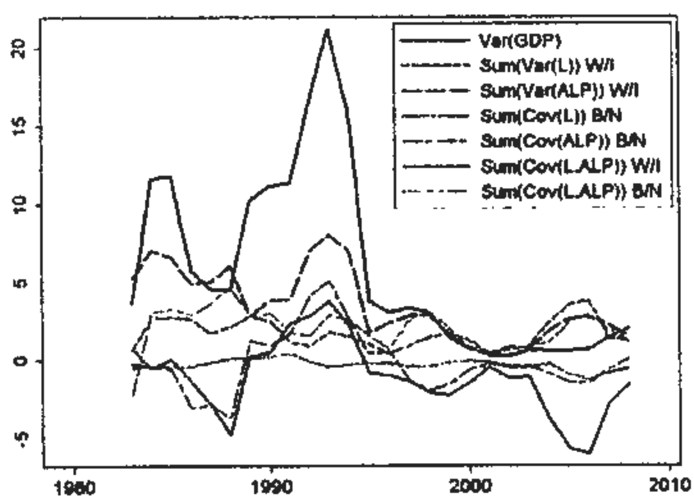

Figure 18 Rolling Variance Decomposition: Sectoral Labor Productivity

Note: Sample period covers 1978 to 2008. GDP, L and ALP represent the sum of sectoral growth contributions, the sum of growth contributions of sectoral employment, and the sum of growth contributions of sectoral labor productivity, respectively. Cov(L) represents the covariances between growth contributions of sectoral employment. Cov(ALP) represents the covariances between growth contributions of sectoral labor productivity. Cov(L,ALP) W/I and B/N represent the covariances of growth contributions of employment and labor productivity within sector and that between sectors, respectively. The rolling variance decomposition is calculated using a window of 5 years.

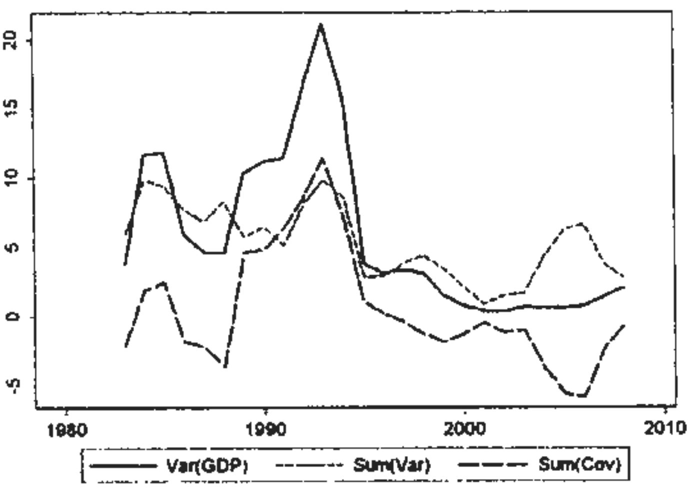

Figure 19 Rolling Variance Decomposition: Sectoral Labor Productivity (Sum)

Note: Sample period covers 1978 to 2008. GDP represents the sum of sectoral growth contributions. Sum(Var) and Sum(Cov) represent the sum of variances terms and the sum of covariances terms of growth contributions of sectoral employment and sectoral labor productivity, respectively. The rolling variance decomposition is calculated using a window of 5 years.

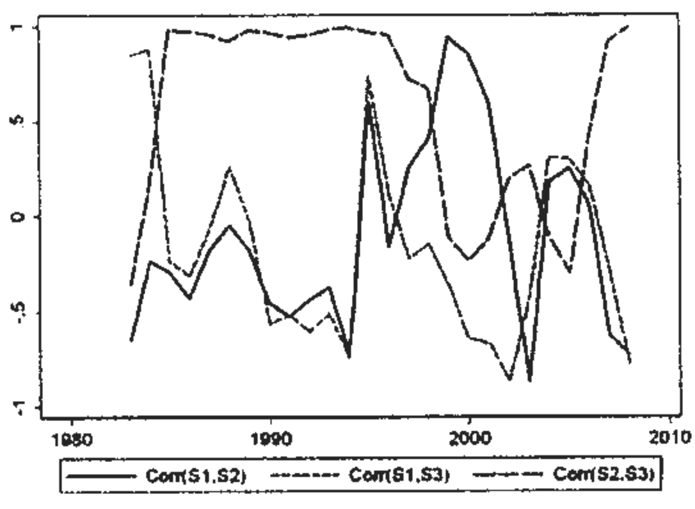

Figure 20 Rolling Pairwise Correlation Between Sectoral Growths

Note: Sample period covers 1978 to 2008. S1, S2 and S3 represent growth contributions of the primary, secondary and tertiary sector, respectively. The weight for computing the average correlation is the average nominal sectoral share in GDP over a rolling window of 5 years.

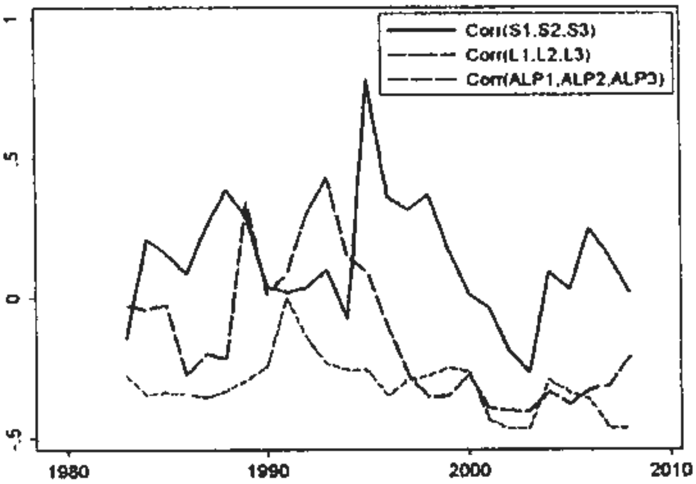

Figure 21 Rolling Average Between-Sector Correlations: Value-Added, Employment and Labor Productivity

Note: Sample period covers 1978 to 2008. S1, S2 and S3 represent growth contributions of the primary, secondary and tertiary sector, respectively. L1, L2 and L3 represent growth contributions of employment of the primary, secondary and tertiary sector, respectively. ALP1, ALP2, and ALP3 represent growth contributions of labor productivity of the primary, secondary and tertiary sector, respectively. The weight for computing the average correlation is the average nominal sectoral share in GDP over a rolling window of 5 years.

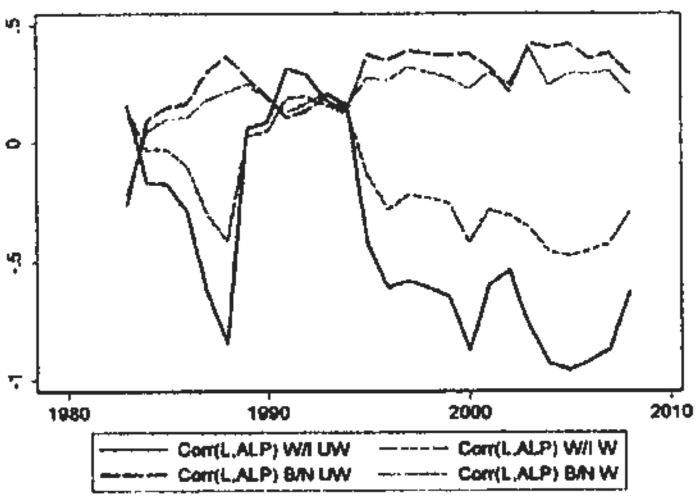

Figure 22 Rolling Average Within- and Between-Sector Correlations Between Employment and Labor Productivity Growth

Note: Sample period covers 1978 to 2008. L and ALP represent growth contributions of sectoral employment and sectoral labor productivity, respectively. W/I and B/N represent within-sector and between-sector correlation, respectively. UW and W represent unweighted and weighted correlation, respectively. The weight for computing the average correlation is the average nominal sectoral share in GDP over a rolling window of 5 years.

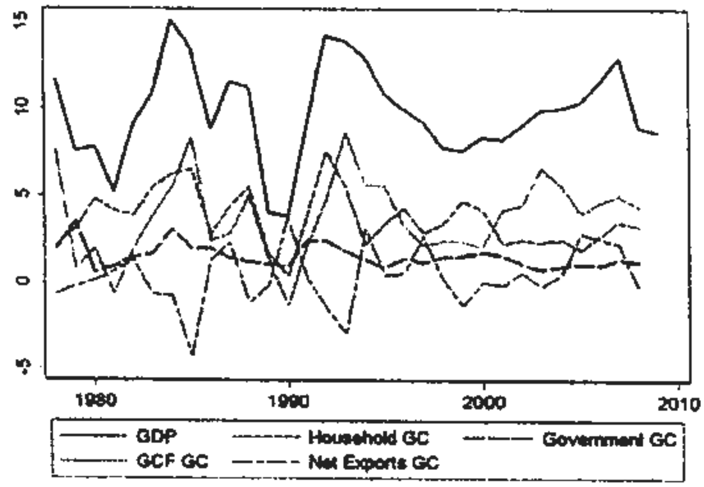

Figure 23 Growth Decomposition: Expenditure Approach

Note: Sample period covers 1978 to 2008. GDP, Household GC, Government GC, GCF GC, and Net Exports GC represent the sum of growth contributions of all expenditure components, growth contributions of household consumption, government consumption, gross capital formation and net exports, respectively.

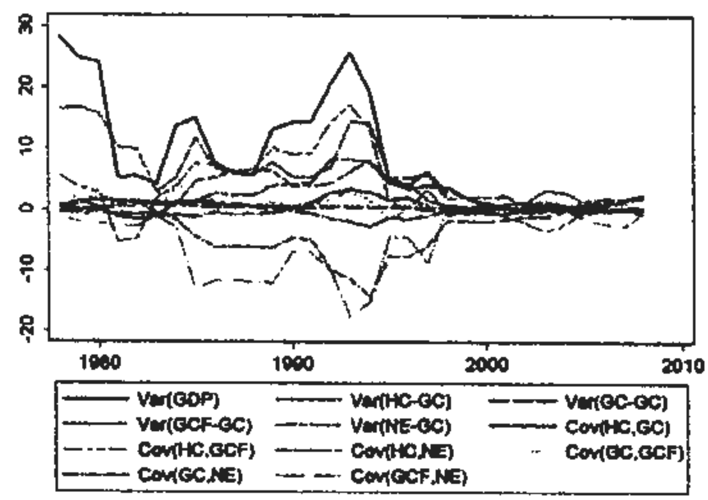

Figure 24 Rolling Variance Decomposition: Expenditure Approach

Note: Sample period covers 1978 to 2008. GDP, HC-GC (HC), GC-GC (GC), GCF-GC (GCF) and NE-GC (NE) represent the sum of growth contributions of all expenditure components, growth contributions of household consumption, government consumption, gross capital formation and net exports, respectively. The rolling variance decomposition is calculated using a window of 5 years.

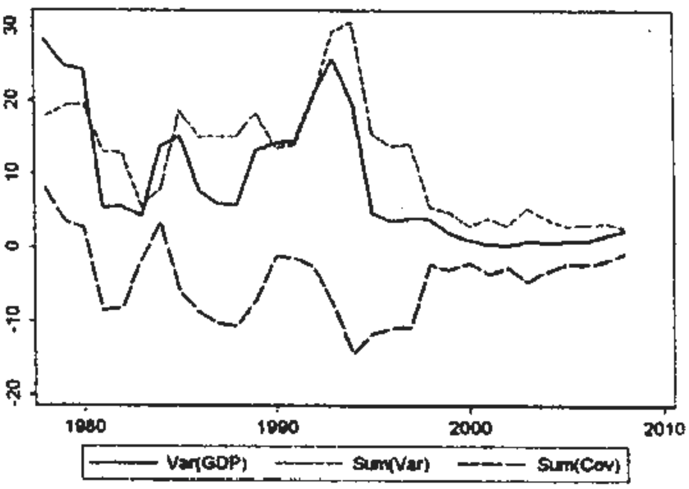

Figure 25 Rolling Variance Decomposition: Expenditure Approach (Sum)
Note: Sample period covers 1978 to 2008. GDP represents the sum of growth contributions of all expenditure components. Sum(Var) and Sum(Cov) represent the sum of variances terms and the sum of covariances terms of growth contributions of expenditure components, respectively. The rolling variance decomposition is calculated using a window of 5 years.

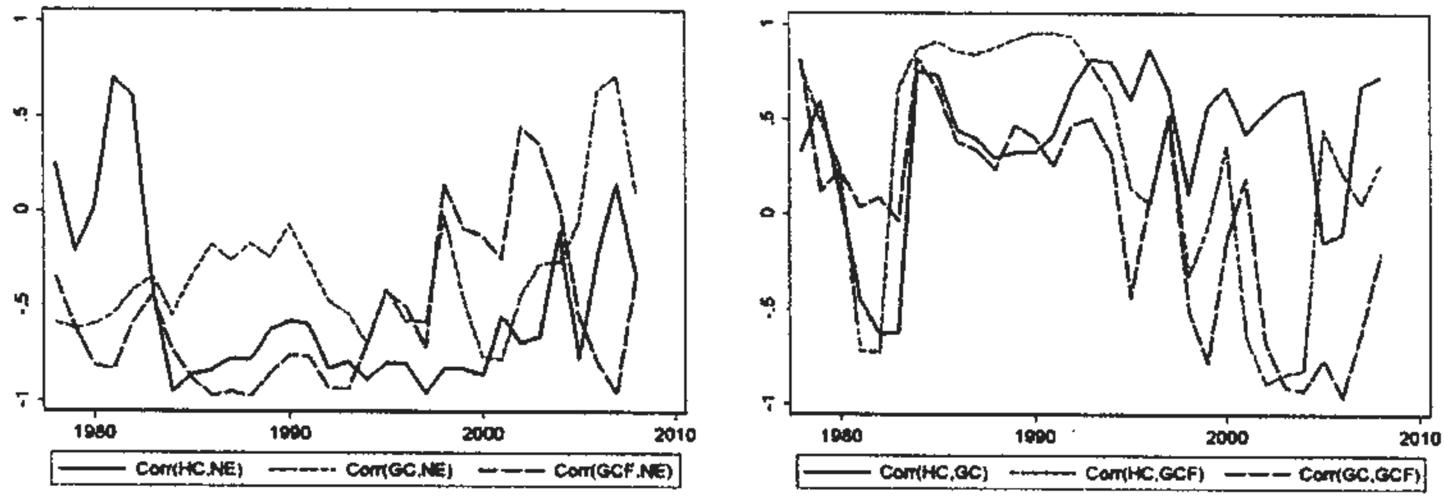

Figure 26 Rolling Pairwise Correlations of Expenditure Components
Note: Sample period covers 1978 to 2008. HC, GC, GCF and NE represent growth contributions of household consumption, government consumption, gross capital formation and net exports, respectively. The weight for computing the average correlation is the average nominal expenditure share in GDP over a rolling window of 5 years.

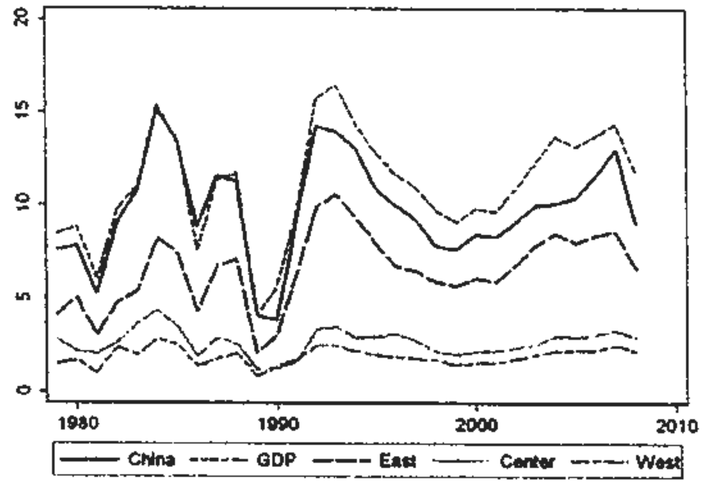

Figure 27 Growth Decomposition: Regional Economies
Note: Sample period covers 1978 to 2008. China and GDP represent national GDP growth and the sum of provincial growth contributions, respectively. East, Center and West represent growth contributions of eastern, central and western group, respectively.

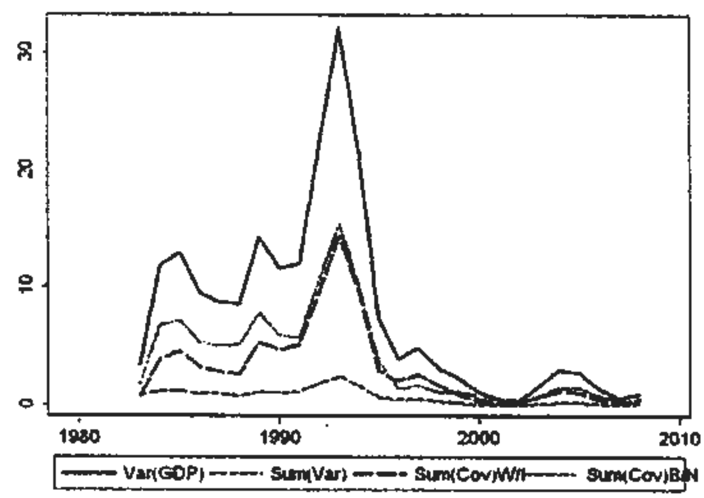

Figure 28 Rolling Variance Decomposition: Regional Economies (Sum)
Note: Sample period covers 1978 to 2008.
Note: GDP represents the sum of provincial growth contributions. Sum(Var), Sum(Cov)W/I, and Sum(Cov)B/N represent the sum of variances terms of provincial growth contributions, the sum of covariances terms of within-group provincial growth contributions, and the sum of covariances terms of between-group provincial growth contributions, respectively. The rolling variance decomposition is calculated using a window of 5 years.

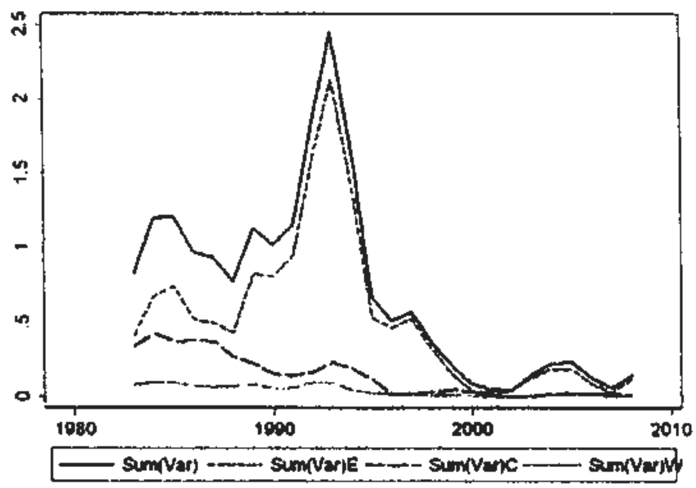

Figure 29 Rolling Variances of Growth Contributions of Three Groups

Note: Sample period covers 1978 to 2008. Sum(Var) represents the sum of variances terms of provincial growth contributions. E, C and W represent eastern, central and western group, respectively. A rolling window of 5 years is used.

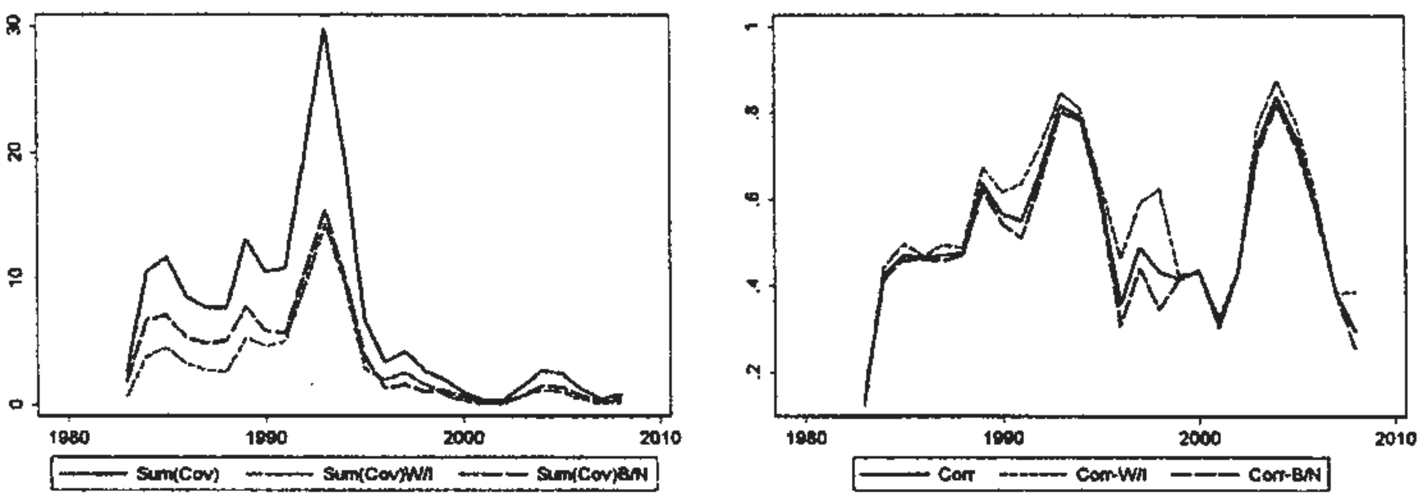

Figure 30 Rolling Covariance and Correlations Within and Between Groups

Note: Sample period covers 1978 to 2008. Sum(Cov) and Corr represents the sum of covariances terms and thê average correlation between provincial growth contributions, respectively. W/I and B/N represent within-group estimate and between-group estimate, respectively. The weight for computing the average correlation is the average nominal sectoral share in GDP over a rolling window of 5 years.

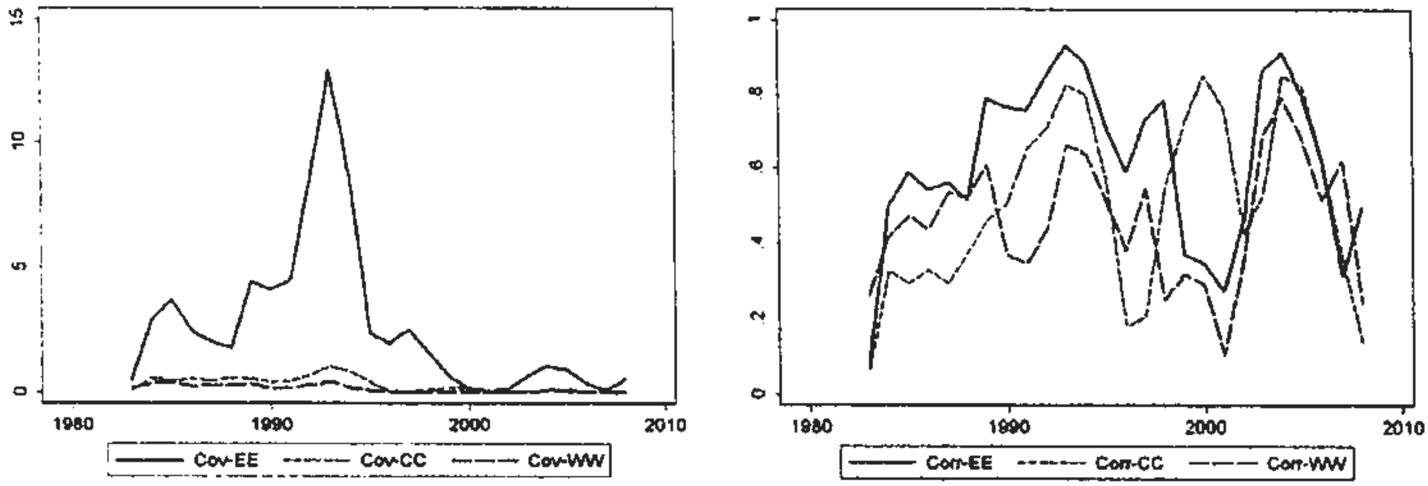

Figure 31 Rolling Covariance and Correlations Within Groups

Note: Sample period covers 1978 to 2008. Cov and Corr represent the sum of covariances terms and the average correlation between provincial provinces, respectively. EE, CC and WW represent the estimates are within western group, within central group and within western group, respectively. The weight for computing the average correlation is the average nominal sectoral share in GDP over a rolling window of 5 years.

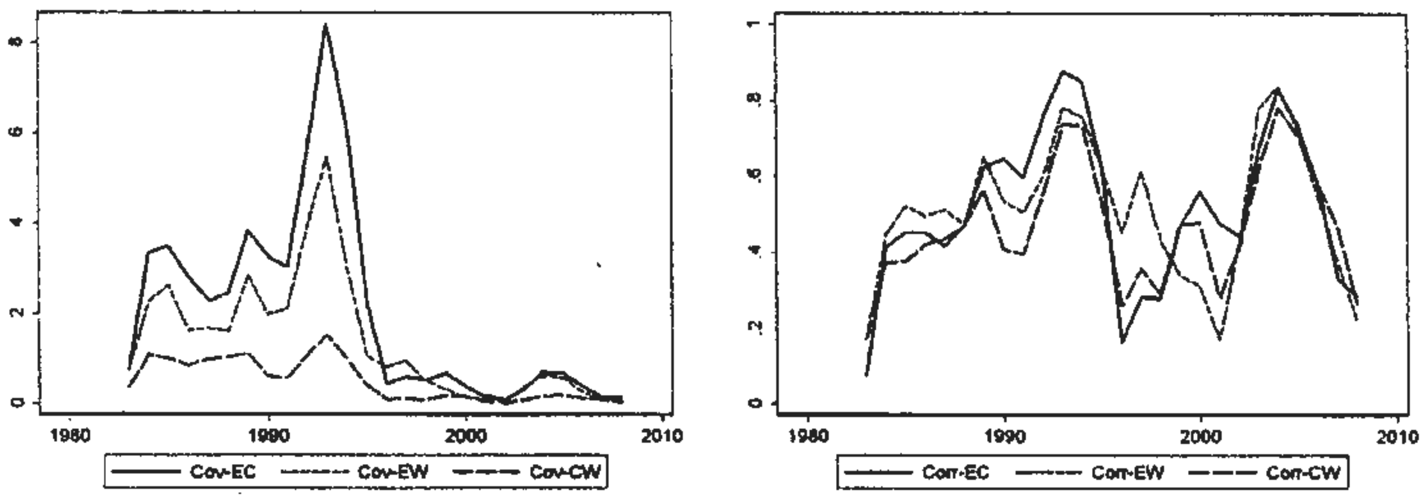

Figure 32 Rolling Covariance and Correlations Between Groups

Note: Sample period covers 1978 to 2008. Cov and Corr represent the sum of covariances terms and the average correlation between provincial provinces, respectively. EC, EW and CW represent the estimates are between eastern and central group, between eastern and western group, and between central and western group, respectively. The weight for computing the average correlation is the average nominal sectoral share in GDP over a rolling window of 5 years.

Appendix

Table A1 Simple Analysis on the Time Trend of GDP Growth (PQA)

	(1) Level	(2) Level	(3) D1	(4) D1	(5) DM^2	(6) DM^2	(7) DM^2
Time trend	0.0102	0.00500	-0.00231	-0.00257	-0.225***	-0.204**	-0.207**
	(0.0104)	(0.0102)	(0.0128)	(0.0112)	(0.0845)	(0.0883)	(0.0918)
Constant	8.743***	6.700***	0.225	0.253	33.09***	30.59***	30.63***
	(0.779)	(1.071)	(0.959)	(0.841)	(6.309)	(7.099)	(7.774)
First lag		0.260***		-0.516***		0.0492	0.0509
		(0.0861)		(0.0774)		(0.0899)	(0.0909)
Second lag							0.00962
							(0.0907)
Observations	127	126	126	125	127	126	125
Adjusted R^2	-0.000	0.058	-0.008	0.255	0.046	0.035	0.028

Note: Level, D1, and DM^2 indicate level, first difference, and square of demeaned series of annualized quarter-over-quarter quarterly GDP growth (PQA), respectively. ***, ** and * represent significance at 1%, 5% and 10% level, respectively. Values in the parenthesis are standard error.

Table A2 Simple Analysis on the Time Trend of GDP Growth (HP)

	(1) Level	(2) Level	(3) D1	(4) D1	(5) DM^2	(6) DM^2	(7) DM^2
Time trend	-1.11e-10	0.000648	0.000621	0.000111	-0.0566***	-0.0133	-0.0166*
	(0.00497)	(0.00220)	(0.00225)	(0.00228)	(0.0139)	(0.00937)	(0.00948)
Constant	9.20e-09	-0.0656	-0.0644	-0.0194	7.903***	1.763**	2.140***
	(0.370)	(0.164)	(0.168)	(0.171)	(1.031)	(0.795)	(0.816)
First lag		0.896***		0.0638		0.781***	0.864***
		(0.0390)		(0.0893)		(0.0560)	(0.0893)
Second lag							-0.110
							(0.0892)
Observations	128	127	127	126	128	127	126
Adjusted R^2	-0.008	0.807	-0.007	-0.012	0.110	0.651	0.657

Note: Level, D1, and DM^2 indicate level, first difference, and square of demeaned series of HP filtered GDP, respectively. ***, ** and * represent significance at 1%, 5% and 10% level, respectively. Values in the parenthesis are standard error.

Table A3 Simple Analysis on the Time Trend of GDP Growth (BP)

	(1) Level	(2) Level	(3) D1	(4) D1	(5) DM^2	(6) DM^2	(7) DM^2
Time trend	0.00570	0.000182	-3.37e-05	-0.000370	-0.0885***	-0.0162*	-0.0203***
	(0.00637)	(0.00182)	(0.00183)	(0.000876)	(0.0146)	(0.00839)	(0.00481)
Constant	-0.596	-0.00641	0.0169	0.0405	9.473***	1.583**	2.181***
	(0.453)	(0.131)	(0.130)	(0.0629)	(1.040)	(0.692)	(0.401)
First lag		0.960***		0.866***		0.860***	1.592***
		(0.0278)		(0.0472)		(0.0481)	(0.0556)
Second lag							-0.821***
							(0.0547)
Observations	104	103	103	102	104	103	102
Adjusted R^2	-0.002	0.922	-0.010	0.768	0.257	0.826	0.947

Note: Level, D1, and DM^2 indicate level, first difference, and square of demeaned series of BP filtered GDP, respectively. ***, ** and * represent significance at 1%, 5% and 10% level, respectively. Values in the parenthesis are standard error.

Table A4 Tests for Structural Break of GDP Growth: AR(2) Model

Null	GDP growth (FQ)			GDP growth (HP)			GDP growth (BP)		
	Sup	Exp	Ave	Sup	Exp	Ave	Sup	Exp	Ave
A: Variance									
$\sigma_1^2 = \sigma_2^2$	7.46	2.55	3.37	9.34	3.26	3.84	35.45	15.96	21.27
	(0.10)	(0.03)	(0.03)	(0.04)	(0.01)	(0.02)	(0.00)	(0.00)	(0.00)
Estimated Break	1993Q3			1992Q2			2001Q2		
B: Others									
$\mu_1 = \mu_2$	1.73	0.15	0.21	3.07	0.21	0.26	2.08	0.24	0.34
	(0.91)	(0.95)	(0.95)	(0.61)	(0.82)	(0.91)	(0.83)	(0.76)	(0.82)
Estimated Break		None			None			None	
$\phi_{11} = \phi_{12}$	3.04	0.23	0.27	4.62	0.74	0.91	5.15	0.68	0.74
	(0.62)	(0.79)	(0.90)	(0.34)	(0.31)	(0.39)	(0.27)	(0.34)	(0.49)
Estimated Break		None			None			None	
$\phi_{21} = \phi_{22}$	3.14	0.22	0.26	3.06	0.57	0.79	5.32	0.90	0.91
	(0.60)	(0.80)	(0.91)	(0.61)	(0.41)	(0.46)	(0.26)	(0.24)	(0.39)
Estimated Break		None			None			None	
$\mu_1 = \mu_2, \phi_{i1} = \phi_{i2}$	12.68	3.70	2.35	8.51	1.56	1.88	12.96	3.16	2.88
	(0.10)	(0.09)	(0.59)	(0.40)	(0.58)	(0.76)	(0.09)	(0.14)	(0.43)
Estimated Break	2005Q1			None			1984Q2		

Note: Sample period covers 1979Q1 to 2009Q4. FQ, HP and BP represent four-quarter GDP growth, HP filtered GDP sereis, and BP filtered GDP series respectively. Sup, Exp, and Ave represent the statistic $supF_n$, $expF_n$, and $aveF_n$, respectively. Values in the parenthesis are asymptotical p-values.

Table A5 Tests for Structural Break of GDP Growth: AR(3) Model

	GDP growth (FQ)			GDP growth (HP)			GDP growth (BP)		
Null	Sup	Exp	Ave	Sup	Exp	Ave	Sup	Exp	Ave
A: Variance									
$\sigma_1^2 = \sigma_2^2$	7.01	2.50	3.41	8.31	2.78	3.38	25.49	10.82	14.87
	(0.12)	(0.03)	(0.03)	(0.07)	(0.02)	(0.03)	(0.00)	(0.00)	(0.00)
Estimated Break	1993Q1			1992Q2			2002Q2		
B: Others									
$\mu_1 = \mu_2$	3.85	0.21	0.25	3.07	0.15	0.20	2.08	0.18	0.24
	(0.46)	(0.82)	(0.92)	(0.61)	(0.94)	(0.97)	(0.83)	(0.88)	(0.93)
Estimated Break		None			None			None	
$\phi_{11} = \phi_{12}$	6.07	0.38	0.29	4.56	0.90	1.12	1.63	0.20	0.28
	(0.19)	(0.58)	(0.88)	(0.35)	(0.24)	(0.30)	(0.93)	(0.84)	(0.89)
Estimated Break		None			None			None	
$\phi_{21} = \phi_{22}$	6.92	0.48	0.29	3.15	0.80	1.09	1.64	0.20	0.29
	(0.13)	(0.48)	(0.88)	(0.60)	(0.28)	(0.31)	(0.93)	(0.83)	(0.87)
Estimated Break		None			None			None	
$\phi_{31} = \phi_{32}$	7.20	0.53	0.29	1.35	0.19	0.27	2.25	0.32	0.45
	(0.12)	(0.44)	(0.88)	(0.98)	(0.86)	(0.89)	(0.79)	(0.65)	(0.72)
Estimated Break		None			None			None	
$\mu_1 = \mu_2, \phi_{i1} = \phi_{i2}$	18.82	6.12	3.19	11.44	3.67	4.19	20.57	6.19	5.00
	(0.02)	(0.02)	(0.62)	(0.30)	(0.19)	(0.38)	(0.01)	(0.02)	(0.23)
Estimated Break	2005Q4			None			2004Q3		

Note: Note: Sample period covers 1979Q1 to 2009Q4. FQ, HP and BP represent four-quarter GDP growth, HP filtered GDP sereis, and BP filtered GDP series, respectively. Sup, Exp, and Ave represent the statistic $supF_n$, $expF_n$, and $aveF_n$, respectively. Values in the parenthesis are asymptotical p-values.

Table A6 Parameter Estimates and Related Tests for Markov Switching Model (FQ)

	AR(1)	MSH-2		MSMH	
		Regime 1	Regime 2	Regime 1	Regime 2
A: Model Estimation					
δ or μ	10.15 ***	9.76 ***		11.13 ***	9.48 ***
	(1.19)	(1.01)		(2.57)	(1.15)
φ	0.89 ***	0.88 ***		0.88 ***	
	(0.05)	(0.05)		(0.05)	
σ	1.38	1.90 ***	0.90 ***	1.90 ***	0.90 ***
	(0.16)	(0.38)	(0.13)	(0.38)	(0.11)
Log Likelihood	-213.87	-202.03		-201.84	
SIC	-221.09	-216.47		-218.69	
AIC	-218.59	-211.46		-212.84	
HQIC	-216.87	-208.03		-208.84	
B: Residual Diagnostic					
Ljung-Box Q(8)	28.19***	20.10 ***		19.81***	
Ljung-Box Q2(8)	16.82**	13.45 *		11.46	
Skewness	-0.91	-0.34		-0.41	
Kurtosis	7.49	3.35		3.36	
Jarque-Bera	120.47***	3.00		4.19	
C: Instability Tests (Nyblom-Hansen L test)					
Joint	1.05 **	0.66		0.80	
δ or μ	0.05	0.06		0.05	0.08
φ	0.03	0.04		0.04	
σ^2	0.63 **	0.04	0.17	0.04	0.20
D: Transition Probability					
P(R1|-)	-	0.972	0.015	0.972	0.015
P(R2|-)	-	0.028	0.985	0.028	0.985
E: Regime Classification					
Quarters	-	81Q1-92Q4	79Q2-79Q4 93Q1-09Q4	81Q1-92Q4	79Q2-79Q4 93Q1-09Q4
Durations	-	48	75	48	75

Note: Sample period covers 1979Q1 to 2009Q4. FQ indicates the series is four-quarter GDP growth. Ljung-Box $Q_1(8)$ and $Q_2(8)$ indicate Liung-Box Q statistics for autocorrelations with 8 lags for standardized residuals and squared standardized residuals, respectively. Jarque-Bera is Jarque-Bear statistic for normal distribution of residual. Values in the parenthesis are standard error. ***, ** and * represent significance at 1%, 5% and 10% level, respectively.

Table A7 Mean and Standard Deviation Comparison of GDP Growth for All Provinces

	Mean Comparison			Standard Deviation Comparison		
	1978-1992	1993-2008	Change	1978-1992	1993-2008	Change
Beijing	9.39	11.53	2.14	4.75	1.56	-3.19 **
Tianjin	7.94	13.38	5.44 ***	4.31	2.13	-2.18 *
Hebei	9.24	12.15	2.91 **	4.55	2.43	-2.11 ***
Shanxi	8.37	11.58	3.20 *	5.75	2.28	-3.46 ***
InnerMongolia	9.80	14.34	4.54 **	4.93	4.55	-0.38
Liaoning	8.39	10.83	2.44	5.46	2.50	-2.96 ***
Jilin	9.11	11.34	2.23	6.43	2.64	-3.79 ***
Heilongjiang	6.83	9.88	3.05 ***	2.40	1.63	-0.77
Shanghai	7.99	12.31	4.32 ***	3.50	1.77	-1.73 *
Jiangsu	11.97	13.39	1.42	6.20	2.64	-3.56 **
Zhejiang	12.81	13.61	0.80	6.34	3.52	-2.82 *
Anhui	9.22	11.86	2.64	6.39	2.82	-3.57 ***
Fujian	12.41	13.23	0.81	5.26	3.80	-1.45 **
Jiangxi	9.42	10.78	1.36	4.23	2.47	-1.76 **
Shandong	10.86	13.23	2.38	4.46	2.80	-1.66 **
Henan	10.18	12.08	1.90	5.61	2.60	-3.01 **
Hubei	9.66	11.28	1.62	5.14	2.18	-2.96 ***
Hunan	8.00	10.79	2.79 ***	2.53	1.80	-0.73
Guangdong	13.84	13.68	-0.15	4.78	3.59	-1.19 *
Guangxi	8.36	11.42	3.06 **	4.31	3.10	-1.21
Hainan	12.71	10.02	-2.68	9.74	3.89	-5.85 **
Chongqing	9.06	11.49	2.44 **	3.42	2.39	-1.03
Sichuan	8.71	10.87	2.16 **	3.13	2.00	-1.13 *
Guizhou	9.22	9.78	0.55	4.52	1.63	-2.90 ***
Yunnan	9.67	9.95	0.27	4.12	1.89	-2.24 ***
Tibet	7.60	13.00	5.40 *	10.31	1.98	-8.32 ***
Shaanxi	9.51	11.64	2.12	5.35	1.78	-3.56 ***
Gansu	8.39	10.61	2.23	6.04	1.06	-4.99 ***
Qinghai	6.61	10.44	3.82 *	6.75	1.86	-4.89 ***
Ningxia	8.94	10.45	1.51	4.43	1.61	-2.82 **
Xinjiang	11.29	9.65	-1.64 *	3.02	1.81	-1.21 *

Note: The provinces' names represent the GDP growth of each province. Significance levels of growth change are from a T-test of the null hypothesis of equal mean with unequal variance for the two sub-periods. Significance levels of standard deviation change are from Levene's robust test for the equality of variances for the two sub-periods. ***, ** and * represent significance at 1%, 5% and 10% level respectively.

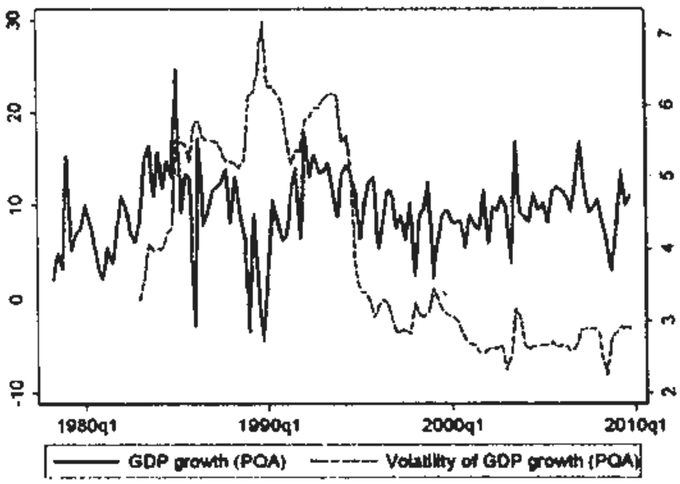

Figure A1 GDP Growth and Rolling Volatility (PQA)

Note: Sample period covers 1978Q1-2009Q4. PQA indicates annualized quarter-over-quarter GDP growth. GDP growth and Volatility of GDP Growth correspond to left scale and right scale respectively.

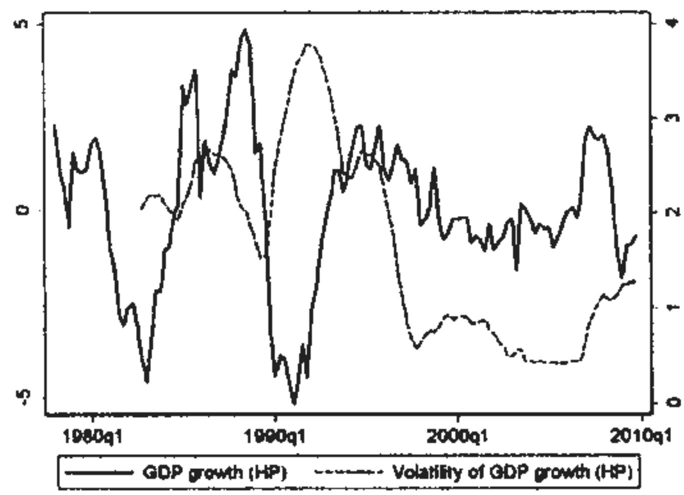

Figure A2 GDP Growth and Rolling Volatility (HP, 1978Q1-2009Q4)

Note: Sample period covers 1978Q1 to 2009Q4. HP indicates HP filtered GDP series. GDP growth and Volatility of GDP Growth correspond to left scale and right scale respectively.

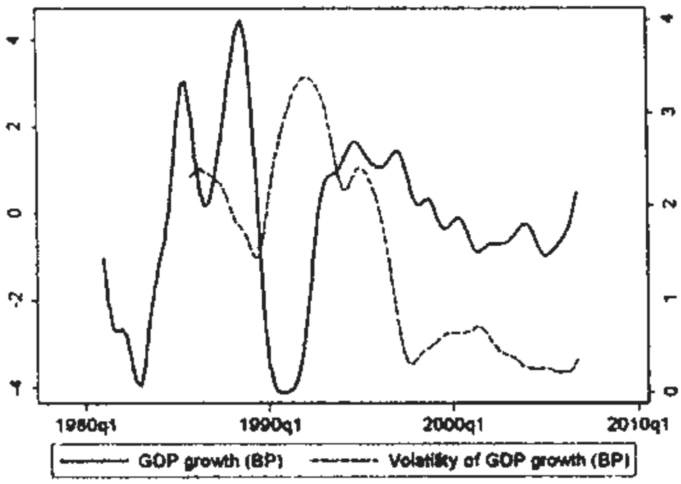

Figure A3 GDP Growth and Rolling Volatility (BP)

Note: Sample period covers 1981Q1 to 2006Q4. BP indicates BP filtered GDP series. GDP growth and Volatility of GDP Growth correspond to left scale and right scale respectively.

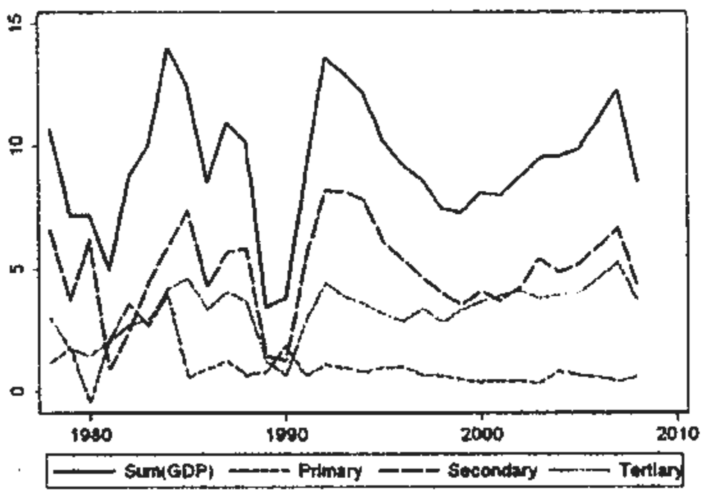

Figure A4 Growth Contribution of Nine Sub-Sectors (Aggregate)

Note: Sample period covers 1978 to 2008. Sum(GDP), Primary, Secondary and Tertiary represent the sum of sectoral growth contributions, growth contribution of the primary sector, the sum of growth contributions of secondary sub-sectors, and the sum of growth contributions of tertiary sub-sectors, respectively.

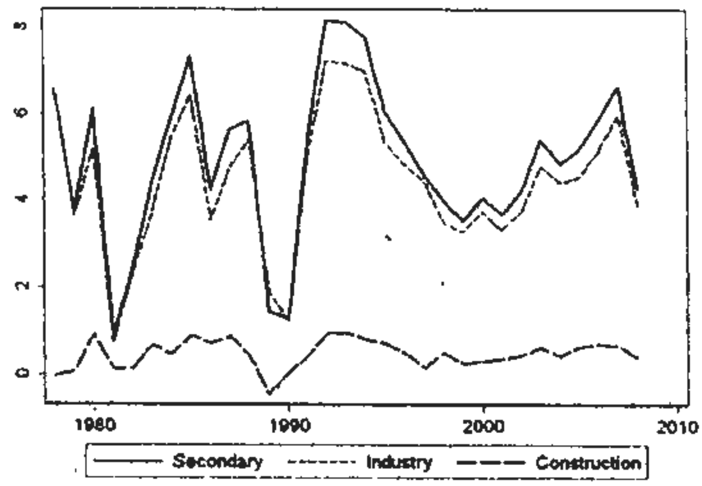

Figure A5 Growth Contribution of Secondary Sector

Note: Sample period covers 1978 to 2008. Secondary, Industry and Construction represent the sum of growth contributions of secondary sub-sectors, growth contribution of industry, and growth contribution of construction, respectively.

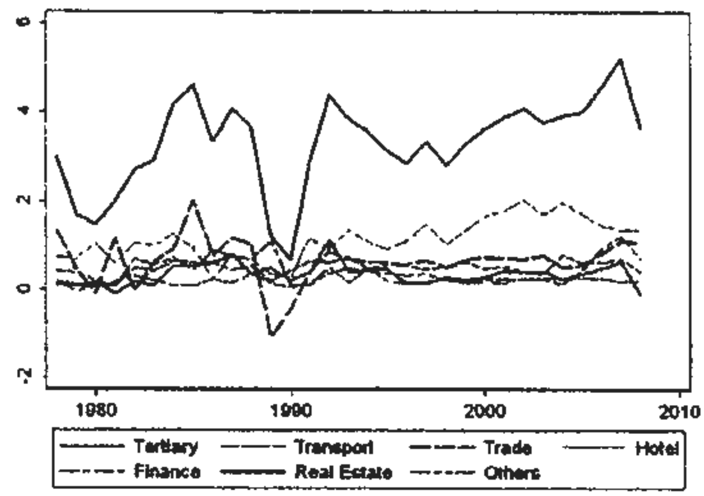

Figure A6 Growth Contribution of Tertiary Sector

Note: Sample period covers 1978 to 2008. Tertiary, Transport, Trade, Hotel, Finance, Real Estate, and Others represent the sum of growth contributions of tertiary sub-sectors, growth contributions of transport, storage and post (Transport), wholesale and retail trades (Trade), hotels and catering services (Hotel), financial intermediation (Finance), real estate (Real Estate), and other tertiary sub-sectors (Others), respectively.

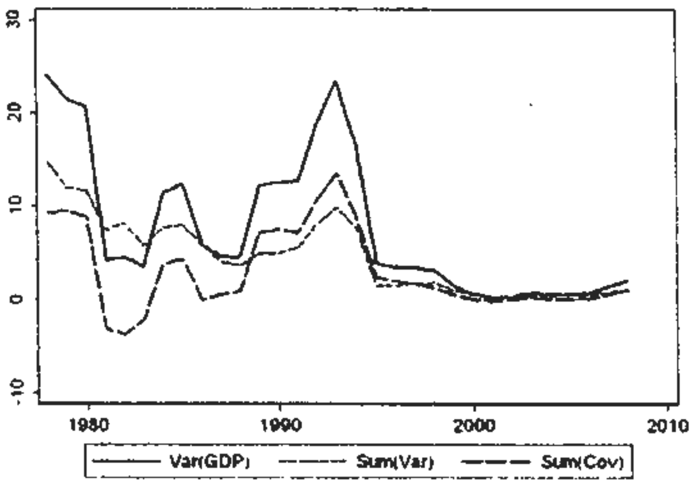

Figure A7 Rolling Variance Decomposition of Nine Sub-Sectors (Sum)
Note: Sample period covers 1978 to 2008. GDP represents the sum of sectoral growth contributions. Sum(Var) and Sum(Cov) represent the sum of variances of sectoral growth contributions and the sum of covariances between sectoral growth contributions, respectively. The rolling variance decomposition is calculated using a window of 5 years.

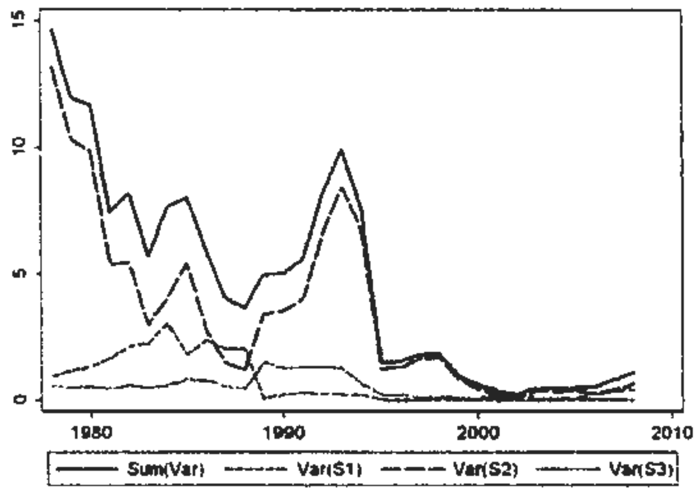

Figure A8 Rolling Sum of Variance of Growth Contribution from Nine Sub-Sectors
Note: Sample period covers 1978 to 2008. Sum(Var), Var(S1), Var(S2), and Var(S3) represent the sum of variances of sectoral growth contributions, the variances of growth contributions of the primary sector, the sum of variances of growth contributions of the secondary sub-sectors, and the sum of variances of growth contributions of tertiary sub-sectors. A rolling window of 5 years is used.

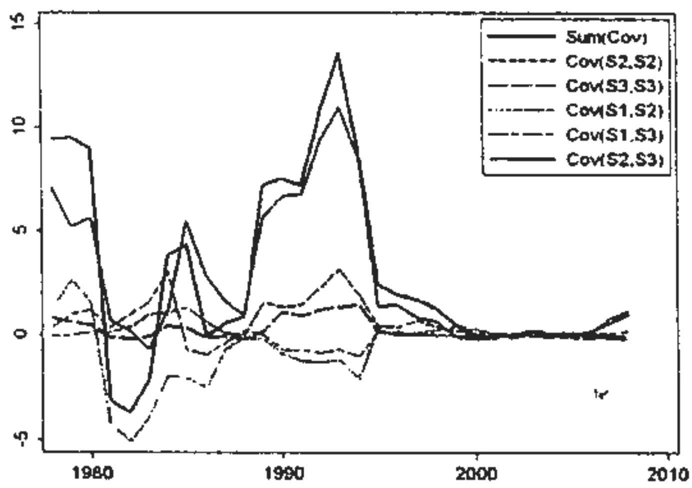

Figure A9 Rolling Sum of Covariances of Growth Contribution from Nine Sub-Sectors

Note: Sample period covers 1978 to 2008. Sum(Cov) represents the sum of covariances of sectoral growth contributions. Cov(S2,S2) and Cov(S3,S3) represent the sum of covariances of sectoral growth contributions within the secondary sector and within the tertiary sector, respectively. Cov(S1,S2), Cov(S1,S3), and Cov(S2,S3) represent the sum of covariances of sectoral growth contributions between primary and secondary sub-sectors, between primary and tertiary sub-sectors, and between secondary and tertiary sub-sectors, respectively. A rolling window of 5 years is used.

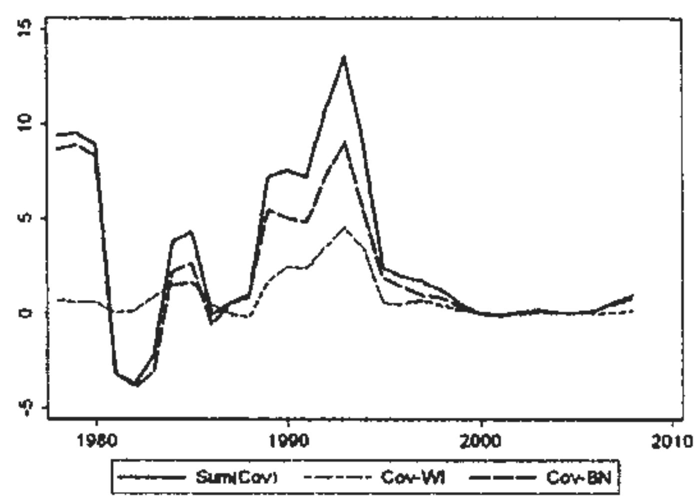

Figure A10 Rolling Sum of Within- and Between-Sector Covariances of Growth Contribution from Nine Sub-Sectors

Note: Sample period covers 1978 to 2008. Sum(Cov), Cov-W/I, and Cov-B/N represent the sum of covariances of sectoral growth contributions, the sum of sectoral growth contributions within sector, and the sum of sectoral growth contributions between sectors. A rolling window of 5 years is used.

What Accounts for the Volatility of China's Economic Growth?

Abstract

This essay attempts to examine the underlying factors accounting for the volatility of China's economic growth. It particularly highlights the role of investment policy volatility in explaining output volatility. The results of cross-sectional and panel regressions from Chinese provincial data suggest a significant and positive link between investment policy volatility and growth volatility. Further, GMM estimations confirm that investment policy volatility amplifies the growth volatility, whereas fiscal policy volatility has no significant effect. Government size and investment share have opposite influences on growth volatility, although they are not always significant. The main findings are robust to the inclusion of additional controls, the substitution of initial values for the mean values of control variables, and the alternative estimation specifications of policy volatilities. It suggests that the decline in investment policy volatility accounts for a significant part of the increasing stability of China's economic growth, and that stable policies and a better institutional environment are crucial in sustaining the macroeconomic stability of China.

JEL: C33, E32, J00, P20

Keywords: Volatility, Discretionary Policy, Policy Volatility, Chinese Economy

1 Introduction

China's economic growth in the reform period has been extensively discussed. Recently, the cyclical pattern of China's economic growth has increasingly attracted attentions among researchers (Brandt and Zhu, 2000; 2001; Young, 2003; Prasad and Rajan, 2006; Brandt and Zhu, 2010). The average GDP growth of China is 9.85%, and its standard deviation is 2.73% from 1978 to 2009. Moreover, it has been documented that a substantial decline in the volatility[30] of China's economic growth is evident during the reform period (Michael, 2004; Gao, 2007; He, Chong and Shi, 2009; Zhang, 2011a).

We simply divide the whole reform period into two sub-periods using 1992 as the break year, the time at which China eventually confirmed its development strategy of incremental reform toward the market economy after south tour speeches of Deng Xiaoping. The volatility of GDP growth in the first sub-period (3.50%) is 1.85 times larger than that recorded in the second sub-period (1.89%).[31] We also find that most of Chinese provinces become increasingly stable in terms of GDP growth as well as in consumption and investment growth (Zhang, 2011a).

What accounts for the volatility of China's economic growth? This issue is not only important to the Chinese economy, but also suggestive for other developing countries, most of which are still suffering from high growth volatility (Kose, Prasad and Terrones, 2006).[32] Despite the argument that the welfare costs of the volatility of aggregate consumption and output are

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[30] In this study, the volatility of economic growth is measured by its standard deviation over a period.

[31] By computing Levene's robust test statistic for the equality of variances, we can reject the equality of standard deviation of the two sub-periods at the 1% significance level.

[32] The median average growth rate of developing countries is 1.57%, and the standard deviation is 4.90% during the period 1961–2000, indicating that developing countries have experienced a low growth rate and high volatility during the past decades (Kose, Prasad and Terrones, 2006).

negligible in the US (Lucas, 2003), some studies have revealed that the welfare gain from reducing volatility is potentially fairly large, especially in the developing countries (Pallage and Robe, 2003; Barlevy, 2004). Moreover, investigating the determinants of growth volatility using data within a country, in particular Chinese provincial data in this essay, can also avoid the international data compatibility problems to a large extent (Barro, 1991; Li and Zhang, 2007).

The determinants of output volatility have been discussed extensively across countries, particularly the issue regarding the "Great Moderation" in the US and other developed economies. The increasing stability of the US economy prior to the recent financial crisis has been attributed to several explanations, such as structural change, good luck of smaller shocks, financial innovations, improved monetary policy, improved inventory management, and demographic changes (Stock and Watson, 2002; Davis and Kahn, 2008; Jaimovich and Siu, 2009). Another important determinant is associated with the aggressiveness of using discretionary fiscal policy, which represents the component of fiscal policy deviating from the current macroeconomic conditions. It is found that the aggressive use of discretionary fiscal policy determined by exogenous institutional factors has a positive effect on growth volatility (Fatás and Mihov, 2003a; 2006).

In the context of Chinese economy, several studies have proposed underlying explanations for the cyclical pattern of its economic growth. For instance, Brandt and Zhu (2000; 2001) propose a general equilibrium analytical framework to attribute the cyclical economic growth of China to decentralization, the government's commitment to state-owned enterprises (SOEs), and imperfect credit control. The tensions between central and local governments about investment decision, and effectiveness of macro-control actions are also considered potential driving forces of Chinese business cycles (Naughton, 1995b; Yu, 1997). More directly, the first essay of my PhD dissertation employs decomposition methods from different perspectives to investigate the sources of the decline in volatility (Zhang, 2011a).

This essay examines the factors accounting for China's growth volatility, with a particular focus on the effect of investment policy volatility on output fluctuation. Following the definition of discretionary fiscal policy (Fatás and Mihov, 2003a), we introduce the undesired investment growth and investment policy volatility in this essay. This factor is important to the Chinese economy not only because investment is the most important driving force of China's economic growth (Young, 1995; Bosworth and Collins, 2008; Prasad, 2009), but also due to the fact that undesired investment (i.e., over-investment or under-investment) arising from the "investment hunger" of the local governments and their investment policies is quite common among Chinese provinces (Prasad, 2009; Qin and Song, 2009). Higher growth volatility is often coupled with higher investment policy volatility, which is defined as the standard deviation of undesired investment growth.

The main conclusion of this essay is that the investment policy volatility has a significant and positive effect on growth volatility among Chinese provinces. Using Chinese provincial data over the period 1978–2008, we obtain qualitatively consistent results of the positive link between investment policy volatility and output volatility from both OLS and panel regressions. Furthermore, the GMM approach is employed to solve the simultaneity and endogeneity problem. The results of both difference and system GMM estimations suggest a statistically significant and positive effect of investment policy volatility on output volatility. Unlike the cross-country evidence, the effect of fiscal policy volatility is insignificant in most specifications. We also find that the government share and investment share affect the growth volatility negatively and positively, respectively, although the significance levels vary among different cases.

To verify the robustness of our main result regarding the positive effect of investment policy volatility on growth volatility, we conduct several robustness tests. First, some other potential explanations for China's growth volatility are considered, including SOE reform, demographic change, trade openness, financial development, and human capital. Second, the initial conditions of government size and investment share are used instead of their mean values. Alternative specifications of fiscal and investment policy volatility are employed to test the robustness of our results as well. The positive role of investment policy volatility remains significant in all specifications. This essay concludes that a better institutional environment, which stems from stable and predictable policies of far-sighted local governments and benign interactions between the government and market, is crucial to the macroeconomic stability of the Chinese economy.

The rest of the essay is organized as follows: Section 2 documents the dynamics of growth volatility of China; Section 3 introduces the main focus of our study, which is the fiscal policy volatility and investment policy volatility; Section 4 discusses other potential factors affecting growth volatility; Section 5 contains the data description; Section 6 reports the benchmark empirical results; robustness tests are conducted in Section 7; and Section 8 presents the conclusion.

2 Volatility of the Chinese Economy

The average real GDP growth of China over the years 1978–2009 is 9.85%, which is considered the most outstanding economic performance all over the world. Meanwhile, growth volatility, which is measured by the standard deviation of real GDP growth, is also substantial, reaching 2.73% in the reform period. Figure 1 illustrates the rolling standard deviation of the annual real GDP growth with a rolling window of 5 years.[33] It also shows that, the volatility of GDP growth declines over time from about 5% in the early 1980s and early 1990s to less than 1% in the early 2000s, except for a mild increase recently due to the global financial crisis. Using data on quarterly GDP growth, it has been proven that the volatility of China's economic growth experienced only a one-time structural break around 1992 and 1993 (Zhang, 2011a).

[FIGURE 1 HERE]

Moreover, we also find a similar pattern in the output volatility of most provinces to that at the national level. Most provinces experience a notable decline in output volatility in the reform period. Here, we divide the whole period into two sub-periods, the first one covered 1978–1992 and the second one covered 1993–2008. Table 1 presents the comparison of the variance of the real GDP growth of the two sub-periods for 31 provinces. We employ Levene's robust test to calculate the significance level of volatility change under the null hypothesis of no difference in growth volatility between the two sub-periods.

Table 1 indicates that all provinces became more stable in the second sub-period, with 26 out of 31 provinces experiencing a significant decline in growth volatility at least at the 10% level. Given that we have low data quality or short time-series for the provinces of Tibet and Chongqing, we exclude them in the following discussions. Among all other 29 provinces, Hainan (9.74%) and

[33] A window of 5 years is used so that the volatility at year t is the standard deviation over year t-4 to t.

Inner Mongolia (4.55%) suffer the highest growth volatility in the first and second sub-periods, respectively. Meanwhile, Hainan (5.85%), Gansu (4.99%), and Qinghai (4.89%) experienced the largest volatility decline between the two sub-periods.

[TABLE 1 HERE]

3 Policy Factors

3.1 Fiscal Policy

According to Keynesian theory, fiscal policies can smooth out the business cycle volatility by expansionary government spending during recessions and contractionary fiscal policies during expansions. A significant and negative link between government size and volatility is observed across OECD countries and across US states (Fatás and Mihov, 2001). Andres, Domenech, and Fatás (2008) also provide a theoretical analysis to reveal the negative relationship between government size and output volatility using a modified real business cycle model. Therefore, there is an argument for not tying the government's hands for the purpose of reducing the amplitude of business cycles (Levinson, 1998). On the other hand, some studies have argued that unrestricted fiscal policies or those driven by the considerations not associated with macroeconomic conditions lead to excessive deficits and unsustainable level of debt, thus becoming sources of macroeconomic instability (Fatás and Mihov, 2006). The recent European sovereign debt crisis is an example of the detrimental effect of fiscal policies that are not compatible with the economic conditions of a country on economic growth and stability. Moreover, Lane (2003) also finds that fiscal policies are not always counter-cyclical, but pro-cyclical and amplifying the business cycles in some volatile OECD countries.

As a result, the fiscal policy can be divided into two parts, namely, non-discretionary and discretionary fiscal policy. The non-discretionary component represents the effect of fiscal policies on auto-stabilizing business cycle fluctuation and responding to the current economic state. The discretionary one reflects the fiscal policies that deviate from the current macroeconomic conditions (Fatás and Mihov, 2003b; Galí and Perotti, 2003). The non-discretionary fiscal policies are found to be counter-cyclical and can smooth business cycle volatility for European countries as well as for US states (Galí and Perotti, 2003; Fatás and Mihov, 2006; Candelon, Muysken and Vermeulen, 2010). However, the role of discretionary fiscal policies is more controversial. Galí and Perotti (2003) find that discretionary fiscal policies are pro-cyclical before 1992 and are counter-cyclical after 1992 for European countries. Candelon, Muysken, and Vermeulen (2010) re-examine this issue and find a consistently pro-cyclical effect, suggesting that discretionary fiscal policies amplify business cycle fluctuations for European countries. More importantly, Fatás and Mihov (2003a) focus only on the aggressiveness of using discretionary fiscal policy, revealing that the more aggressive use of discretionary fiscal policy results in higher aggregate volatility across countries.

Turning to the case of China, fiscal policies and government expenditure play an important role in reducing income inequality and smooth business cycle fluctuation, especially after the tax reform in 1994. Local governments have increased the public expenditure significantly in the reform period. The average provincial government expenditure share in GDP has increased from 8.5% in 1978 to 15.8% in 2008, coinciding with the decline of growth volatility. During the recent financial crisis, government spending contributed a substantial part in reducing the magnitude and consequence of economic downside risk. Moreover, substantial tax reforms have been launched in 1994 to increase the fiscal capacity of the Chinese central government. The fiscal transfer from the central government to those provinces lacking in fiscal capacity is supposed to reduce the income inequality among provinces and enhance the role of the stabilizer of fiscal policies (He, 2008).

However, the aggressive use of fiscal policy is common in Chinese provinces; such an act can be attributed to several distinct features of the Chinese economy. The first consideration stems from the effect of political promotion rule of local officials. The promotion of local officials is mainly determined by local growth performance (Li and Zhou, 2005), as well as their supervisor's perception of local public management. The latter is mostly financed by the government expenditure. To achieve some political goals that are not associated with either the auto-stabilizer role or the current state of local economy, local officials expand the government expenditure when needed, and reduce the spending when it is deemed unnecessary for them. The aggressive use of discretionary fiscal policy may lead to higher deficit and debt, thus hindering the stability of provincial economy.

The second consideration arises from the dominant role of the government in China's economic growth, which partly reflects the persistent influence of the long-term planned economic system of China. It is also associated with the promotion incentive of local officials, because the better economic performance, the higher probability that they can be promoted. Government expenditure and government investment are treated as important and direct instruments, with which to stimulate economic growth and smooth the business cycles in China. However, aside from the non-discretionary fiscal policies aiming to stabilize the economy, local governments may aggressively expand government expenditures regardless of the real economic need and their fiscal capacity. For instance, to combat the recent financial crisis, China initiated an unprecedented expenditure and investment plan amounting to RMB 4 trillion, most of which are financed by the local governments. Provinces with limited fiscal capacity but have aggressive government expenditure plans must raise a large amount of funds through the local government finance vehicle (LGFV) and through loans and debts.[34] However, the unsustainable government expenditure growth funding by loans and debts will eventually fall into stagnation. Hence, this fiscal policy volatility may directly result in output volatility. On the other hand, the skyrocketing level of local government debt may corrode the credibility of local government and hamper the health of local banking system. The local government debt is now becoming an increasing threat to the long-term growth and stability of the country.

To isolate the discretionary component from the fiscal policy in the context of the Chinese economy, we follow Fatás and Mihov (2003a) and run the following regression for each province over the last three decades (1978–2008):

$$\Delta \ln G_t = \alpha + \beta \ln G_{t-1} + \gamma \Delta \ln Y_t + \phi X_t + \varepsilon_t^F , \quad (1)$$

where G_t is the real government expenditure, Y_t is the real GDP, X_t represents the other factors affecting the government expenditure growth, and ε_t^F is the residual term. To address the endogeneity problem of economic growth in the baseline regression of Equation 1, we instrument the current

[34] According to the report of the Peoples' Bank of China (PBoC), by the end of 2010, the number of LGFVs is more than 10 thousand, while the amount of loans through LGFV is less than 30% of total loan. As estimated, the amount through LGFV will exceed RMB 10 trillion, and the total debt ratio over GDP will reach 40% by the end of 2011 based on the research reports of the CICC and CITI Group.

GDP growth with its lagged value and lagged inflation. Some other factors, including inflation and inflation square, are included in X_t.[35]

The province-specific volatility of residual term $\varepsilon_{i,t}$ is considered as a quantitative estimate of the aggressiveness of using discretionary fiscal policy. Thus, we calculate this volatility as the standard deviation of ε_t, and denote it as σ^F, i.e., $\sigma^F = \sqrt{\mathrm{var}\left(\varepsilon_t^F\right)}$. We consider ε_t as a discretionary spending shock (Alesina et al., 1995; Alesina et al., 2002; Fatás and Mihov, 2003a)[36] and σ^F as the typical size of a discretionary change in fiscal policy or aggressiveness of using discretionary fiscal policy for a specific province. In this study we also define σ^F as "fiscal policy volatility".

Figure 2 illustrates the rolling growth volatility, government expenditure volatility, and fiscal policy volatility of China at the national level with a rolling window of 5 years. It shows that both the government expenditure volatility and fiscal policy volatility become increasingly stable, together with the declining growth volatility.

[FIGURE 2 HERE]

However, the government expenditure volatility and fiscal policy volatility may be affected by the same exogenous factors with growth volatility. We cannot simply associate the increasingly stable aggregate economy with the decline in fiscal policy volatility from the time-series perspective at the national level. Nevertheless, the variations in growth volatility and fiscal policy volatility

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[35] Robustness analysis is conducted in the later sections to verify the effects of different specifications of Equation 1 on our analysis results.

[36] As Fatás and Mihov (2003a) point out, other studies (e.g., Alesina et al., 1995; 2002), have also employed a similar framework to interpret the residual term $\varepsilon_{i,t}$ as a discretionary government spending shock. They use an approach to estimate the discretionary change in fiscal policy as the difference between actual policy and that determined by the macroeconomic conditions in the previous year (Alesina et al., 1995).

among Chinese provinces provide a sound opportunity for us to investigate the effect of fiscal policy volatility on output volatility. Over the last three decades, the fiscal policy volatility in Chinese provinces has varied noticeably. The average provincial fiscal policy volatility is 10.5%, while its standard deviation is 4.7% with a maximum of 23.0% and a minimum of 4.4%. We simply plot the provincial output volatility and fiscal policy volatility over the period 1978–2008 (see Figure 3). However, we cannot find a significant relationship between these two variables, although they are positively linked. Rigorous analysis of the effect of fiscal policy volatility is conducted in later sections.

[FIGURE 3 HERE]

3.2 Investment Policy

Following the discussion about discretionary fiscal policy and fiscal policy volatility, we introduce the concept of investment policy volatility in the context of the Chinese economy.

Investment is regarded as the key driving force of China's economic growth in the reform period (Young, 1995; Bosworth and Collins, 2008; Prasad, 2009). Over the last three decades, China has experienced a shift from a centralized planned economy to a market economy. However, over-investment, which used to be prevalent but detrimental in the planned economy era, has persisted in the reform period. Over-investment refers to the case, in which output growth falls behind investment growth due to the lack of appropriate growth in capital productivity, and is often regarded as "investment hunger" in recent studies (Yu, 1997; Qin and Song, 2009).

In the reform period of China, over-investment may arise from an imperfect capital market, institutional distortion among different regions, and excessive regional competition for capital due to fiscal decentralization (Yusuf, 1994; Naughton, 1995a; Brandt and Zhu, 2000). Tension exists between the central and local governments with regards investment behavior. Once strict restrictions on the credit and investment are lifted, local governments are likely to fall into the investment hunger (Yusuf, 1994; Naughton, 1995a). To attract investment, especially foreign direct investment (FDI), to boost the economy, local governments may provide the investors with favorable and promotional policies, for example, cheap credit, low-cost lands, and tax refunds (Prasad, 2009). They may also require local banks to provide low-interest loans to local SOEs. Even recently, the tendency of over-investment still remains despite some improvement in investment efficiencies (Qin and Song, 2009). The investment hunger and extensive growth pattern do not stop until the central government imposes strict macro-control policies to tame the increasing threat of inflation and economic overheating (Yu, 1997).

[FIGURE 4 HERE]

Figure 4 shows that the investment growth of China has been faster and more volatile than its GDP growth over the reform period. Pronounced investment volatility is associated with the investment hunger of local governments and the implementation of macro-control policies by the central government. Figure 4 also shows that a series of strong macro-control policies comes after each local peak of economic growth, especially in the first half of the reform period.[37] In addition, investment growth and economic growth slow immediately and

[37] China has imposed the macro-control policies in 1979, 1985, 1988, 1993, and 2006–2008 to confront the overheating economic growth in the corresponding previous years (1978, 1984, 1987, 1992, and 2007, respectively). After the first peak year of 1978, Chinese central government decided to spend three years to "adjust, reform, consolidate, and improve" the macro economy in 1979. In 1992, China's investment and GDP growth reached a record high over the reform era. The Chinese central government imposed stringent macroeconomic controls policies in 1993 to deal with the overheating investment and increasing inflation. The most recent macro-control action was initiated in 2006 and lasted for nearly 2 years; this was implemented to tame the speculative investment in several heavy industries and real estate.

substantially after every launch of macro-control policies. This investment cycle results in over-investment in expansion periods and under-investment in the implementation periods of the macro-control policies. The Peoples' Bank of China (PBoC) started to execute the responsibility of a national central bank only after 1993. Before 1993, most of the macro-control policies were administrative decrees and direct controls on credit, which rapidly and sharply slowed down investment and economic growth.[38] The macro-control policies before 1993 were likely to be very effective but made the investment growth and GDP growth rather volatile. Since the 1990s, China has started to incorporate both monetary and fiscal policies into macro-control actions.[39] The use of market-driven monetary policies instead of direct administrative decrees also allows the local governments to rely less on administrative tools and policy instruments to influence the investment behavior.

Over-investment leads to excessive production capacity, decreasing capital productivity, accumulation of non-performing loans in banking system, and erosion of real investment opportunities (Prasad, 2009; Qin and Song, 2009). In addition, volatile investment growth can bring about high efficiency loss due to normally high adjustment costs of investment (Qin and Song, 2009), thereby accounting for a significant part of the aggregate output volatility in the reform period (Zhang, 2011a). However, because total investment is likely to be pro-cyclical and endogenous in the output production, we cannot simply conclude that output volatility mainly results from investment volatility.

[38] For instance, to moderate the overheating economic growth in 1984, the State Council imposed direct administrative decrees to local governments so as to tighten fiscal expenditure and credit in November 1984. The subsequent Government Work Report in 1985 and the Seventh Five-Year Plan continue to highlight the control over investment and credit. Consequently, the growth rate of industrial output declined to lower than 1% in February 1986 from more than 20% in 1985.

[39] The first adjustment of benchmark loan interest rate was made in April 1991. In the most recent macro-control actions during the period 2006–2008, the PBoC increased the benchmark interest rate and required reserve ratios for 8 times and 18 times, respectively.

Moreover, the investment can be decomposed into two components, the desired investment and the undesired investment (over-investment or under-investment). Theoretically, the former can be estimated by investment demand function, which is determined by the desired output and investment cost (Song, Liu and Jiang, 2001; Qin and Song, 2009; Chow, 2010). The latter refers to the difference between the actual investment and the desired investment, and can be considered a deviation from the equilibrium state due to institutional distortion or exogenous shocks. In China, it is more interesting because the investment decision is somehow policy-induced, and the policy stances of both the central and local governments substantially affect subsequent economic activities (Young, 1995; Prasad, 2009).

Here, we consider over-investment (or under-investment) as a proxy for the policies imposed by the local governments in China to promote and attract undesired investment, which deviates from the current economic conditions. Moreover, the aggressiveness of using these policies is also defined as investment policy volatility.

To isolate the undesired investment from the total investment, we follow the conceptual models of production function and investment demand function to consider the over-investment (or under-investment) as the deviation of actual investment from the desired investment (Caballero, Engel and Haltiwanger, 1995; Song, Liu and Jiang, 2001; Qin and Song, 2009). We simply assume that the output Y is produced by the labor input L and capital services K, and that the production function is constant return to scale with Hicks-neutral augmented technology A following the Cobb-Douglas production function. This is given by:

$$Y_t = A_t f(L_t, K_t) = A_t L_t^{\alpha} K_t^{1-\alpha}, \quad (2)$$

A firm with the production function mentioned above maximizes its profit:

$$\pi_t = Y_t - w_t L_t - i_t K_t, \quad (3)$$

where π, w, and i are profit, employment wage and capital cost, respectively.

Using Lagrange multiplier, we have the following first-order condition for a maximum profit for capital and capital cost:

$$i_t = \frac{\partial Y_t}{\partial K_t} = (1-\alpha) A_t L_t^{\alpha} K_t^{-\alpha} = (1-\alpha)\frac{Y_t}{K_t}, \quad (4)$$

$$K_t^* = (1-\alpha)\frac{Y_t^*}{i_t^*}, \quad (5)$$

where Y^*, K^*, and i^* are the desired output, capital input and capital input cost, respectively.

Investment amounts to the flow of capital adjustment:

$$I_t = K_t - (1-\delta) K_{t-1}, \quad (6)$$

where δ is the effective depreciation rate for K. When capital stock is at its desired level K^*, we have the investment demand function:

$$I_t^* = \delta K_t^* = \delta (1-\alpha)\frac{Y_t^*}{i_t^*}, \quad (7)$$

$$\ln I_t^* = \ln \delta + \ln(1-\alpha) + \ln Y_t^* - \ln i_t^*, \quad (8)$$

$$\ln I_t = \ln I_t^* + \theta_t = \left[\ln \delta + \ln(1-\alpha) + \ln Y_t^* - \ln i_t^*\right] + \theta_t. \quad (9)$$

In the simple conceptual framework presented above, we can see that the desired investment is determined by the desired output and capital input cost in opposite directions. The undesired investment (over-investment or under-investment) is defined as the deviation between the desired and actual investment, $\theta = \Delta \ln I_t - \Delta \ln I_t^*$, which is considered a mandated investment in Caballero, Engel, and Haltiwanger (1995), and a measure of allocative efficiency in Qin and Song (2009).

In this study, we follow the conceptual framework, and empirically derive the undesired investment. We do this by running the following simple regression for each province:

$$\Delta \ln I_t = \alpha + \beta \Delta \ln Y_t + \gamma \Delta \ln i_t + \phi X_t + \varepsilon_t^I, \qquad (10)$$

where I_t, Y_t, and i_t are the actual investment, output and capital input cost, respectively.

Following Equation 5, we derive the capital input cost using the actual values of output and capital input. This is expressed as $\Delta \ln i_t = \Delta \ln\left((1-\alpha)\frac{Y_t}{K_t}\right) = \Delta \ln Y_t - \Delta \ln K_t$, where X_t is a set of other variables potentially affecting the investment demand. By default, we included inflation and inflation square in X_t. We also include several others to conduct the robustness test in later sections. Here, ε_t^I is considered a measure of undesired investment growth, which is the difference between the actual investment growth and the desired investment growth. To solve the endogeneity problem, we instrument the current GDP growth and capital input cost with their corresponding lagged values and lagged inflation.

The province-specific standard deviation of the residual term ε_t^I is treated as a measure of undesired investment shock or allocative investment efficiency shock; it is defined as "investment policy volatility," i.e., $\sigma^I = \sqrt{\text{var}(\varepsilon_t^I)}$. In the

Chinese provincial panel data, the labor input is measured as the total employment.[40] The capital input is estimated according to the Perpetual Inventory Methods by the author,[41] and the output elasticity of labor α is calculated as the share of labor compensation in GDP.

[FIGURE 5 HERE]

We plot the rolling growth volatility and investment policy volatility of China in Figure 5. We can find that the investment growth volatility and investment policy volatility become less volatile in the recent decade, coinciding with the decline of the economic growth volatility. Given the important role of investment in China's economic growth, it is expected that the stability of investment growth is crucial to economic growth. However, there is simultaneity problem between investment and economic growth. The investment policy volatility, which is measured by the standard deviation of undesired investment growth, is mostly determined by institutional and geographical factors that are exogenous to economic growth (Fatás and Mihov, 2003a). We can use it to discuss the effect of investment policy volatility on output volatility in the context of the Chinese economy.

Among the Chinese provinces, Sichuan has experienced lower growth volatility (2.6%) and lower investment policy volatility (7.0%) during 1978–2008, whereas Hainan has a higher growth volatility (6.2%) and higher investment policy volatility (15.7%). From the time-series perspective, the average provincial output volatility and investment policy volatility before 1992 are

[40] We adjust the employment data for Jiangsu, Shandong, Hubei and Qinghai, because there is a significant statistical break in their employment data series in the years 1990, 1995, 1990 and 1990, respectively. The adjustment method is based on the approach used by Holz (2009) to adjust the national employment data.

[41] The base year of capital estimation is 1952. We use the GFCF as the investment series, and let the depreciation rate to be 0.09.

4.7% and 18.0%, respectively. After 1992 the values are 2.2% and 7.5%, respectively. The results above show that there is a drastic decline in investment policy volatility, which accompanies the increasing stability of economic growth. We plot the provincial output volatility and investment policy volatility in Figure 6, and find a significant positive relationship between these two variables. Therefore, we hypothesize that the investment policy volatility positively affects the growth volatility of the Chinese provinces.

[FIGURE 6 HERE]

3.3 Monetary Policy

The role of monetary policies has been actively discussed in the dynamics of output volatility. For instance, Boivin and Giannoni (2006) find that better monetary policy, which responds more strongly to inflation expectations, has tamed the economic volatility of the US more effectively. Better monetary policy can result in a more stable inflation, thus reducing the volatility of output growth.

In China, with the establishment of a unified foreign exchange system in 1994, the People's Bank of China (PBoC) began to use the open-market operations to influence the supply of money. Financial and banking reforms, such as changing the interest rate according to macroeconomic conditions, have also been implemented to increase the effectiveness of market-driven monetary tools. The interbank interest rate trading system was first introduced in 1996. With the ending of the credit quota system in 1998, the PBoC included an increasing number of market-driven monetary tools to enhance the effectiveness of policy reactions. Once the PBoC began to employ an increasing number of market-driven monetary tools, inflation and its fluctuations in China have declined substantially, particularly after the early 1990s (see Figure 4).

However, since the monetary policies are homogenous among all provinces, the inflation variations among provinces are not as prominent as growth and volatility variations. Similar patterns of inflation dynamics demonstrated by the Chinese provinces suggest that monetary policies play roughly similar roles across different provinces. The change of inflation volatility is associated with the increasing stability of economic growth, but may account for only a limited part in the provincial heterogeneity of growth volatility. Moreover, inflation and growth may be affected by several factors simultaneously, and they also influence each other as they are the most important aspects of an economy. Here, we simply plot the output volatility and inflation volatility of the Chinese provinces over the reform period shown in Figure 7. The link between output volatility and inflation volatility among Chinese provinces is positive but insignificant. This study investigates the role of inflation volatility in output volatility in later sections.

[FIGURE 7 HERE]

4 Other Potential Explanations

4.1 SOE Reform

One potential explanation of the cyclical pattern of China's economic growth focuses on the SOE reform. Before the early 1990s, SOEs took the responsibility of production, social stability, and other policy burdens (Bai et al., 2000; Bai, Lu and Tao, 2006). Therefore, SOEs are subject to soft budget constraints because the states are accountable for the SOEs with poor performances through credit transfers (Lin, Cai and Li, 1998; Lin and Tan, 1999). Moreover, money creation is the first choice to finance the transfers to SOEs, whereas a flexible indicative credit plan from the central government is a favorable arrangement for local banks to provide loans to more productive non-SOEs. As a result, inflation rises along with economic growth. When the threats of high inflation and economic overheating emerge, the Chinese government shifts the indicative credit plan to the administrative credit plan to tame the rocketing economy, leading to declining economic growth and inflation. A new round of growth and inflation cycle begins as the indicative credit plan is adopted again. As long as SOEs are imposed with policy burdens and are subject to soft budget constraints, the Chinese government has to maintain its commitment on employment and investment growth of the SOEs to sustain the volatile business cycles (Brandt and Zhu, 2000; 2001).

After the early 1990s, the underlying driving forces of economic cycles began to change due to the incremental SOE reforms that gradually remove the policy burdens on the SOEs, and improve the operation efficiency of the SOEs.[42] A significant number of enterprises, especially small and medium ones, have become fully or partially privatized after the early 1990s (Yao, 2005; Jefferson and Su, 2006). Figure 8 shows that in the beginning of the reform period, SOEs accounted for nearly 80% of the total industrial output, urban employment, and investment in fixed assets. The shares of SOEs in economic activity declined continuously in the reform period, and recently, all those shares have dropped to lower than 30%. The SOE reforms relieved the responsibility of the government for poor performances as well as its commitment on the

[42] To promote the development of the old-age insurance and unemployment insurance system, the State Council issued "The Decision on the Reform of Workers' Old-Age Insurance System" and "The Regulation of Involuntary Unemployment Insurance of the State Owned Enterprises' Workers" in 1991 and 1993, respectively. In the late 1990s, a significant number of workers were laid off (*xiagang*) to improve economic performances and alleviate the social security burden of the SOEs. Moreover, modern corporate governance was introduced to SOEs after the Corporate Law was passed in 1994.

employment growth of SOEs. Therefore, the excessive money creation for transfers to SOEs and the shifts from flexible indicative (or market-based) credit plan to administrative credit plan are not necessary. Consequently, the drastic "boom-bust" or "stop-go" cycles may become smoother.

[FIGURE 8 HERE]

According to the explanation above, a province with higher share of SOEs in the economy may be severely affected by the shift of credit plans, thus leading to more volatile economic growth.

4.2 Demographic Change

Jaimovich and Siu (2009) link the change of the age structure of the labor forces to macroeconomic volatility, and argue that the cyclical volatility of market work is U-shaped as a function of age.[43] They find that the changes in the age composition of the labor forces account for a significant part of the dynamics of output volatility in the G7 countries.[44]

[FIGURE 9 HERE]

Since the launch of the one-child policy in 1979, the population growth rate of China started to decrease. The decreased population growth resulted in a drop in the labor share of the young and an increase of labor share of the old people. As Figure 9 shows, the labor force share of the old (age 55 and above) has increased from 7.4% in 1982 to 15.2% in 2006, while that of the young (age 15-29) has decreased from 47.8% in 1982 to 21.9% in 2006.

[43] Jaimovich and Siu (2009) state that young workers experience much greater volatility of employment and working hours than the prime-aged workers over the business cycle; in comparison, those old workers who are close to retirement experience volatility, which is greater than the prime-aged workers but smaller than the young workers.

[44] In particular, Jaimovich and Siu (2009) find that the changes in age composition account for roughly 1/5-1/3 of the decline in the volatility of economic growth in the US.

Following Jaimovich and Siu (2009), we consider the young (age 15–29) and the old (age 55 and above) as the volatile-age group of the labor forces. We find that the volatile-age labor forces remained relatively stable in the 1980s, but started to decline remarkably after the early 1990s (see Figure 9). The pattern of the volatile-age labor share is associated with the significant decline in the output volatility. If China is the case that Jaimovich and Siu (2009) is arguing for the G7 countries, the change in China's output volatility can be affected by the demographic change of the age structure of the labor forces, which is mostly determined by the fertility choices and population policies more than 15 years ago and is exogenous to the current output volatility.

4.3 Other Factors

Recently, Dynan, Elmendorf, and Sichel (2006) argue that financial innovations, such as developments in lending practices and loan markets, have enhanced the ability of households and firms to borrow, and can also explain the reduction of volatility. Beck, Lundberg, and Majnoni (2006) also find that the level of financial development has a stabilizing effect on economic growth.[45] Since its establishment in the 1990s, China's stock market has experienced rapid expansion. The ratio of market capitalization to GDP was only 3.93% in 1992, but surged to 112% by 2010. The Chinese stock market ranks second among the world's largest stock markets. The mid-1990s also witnessed an important change in the Chinese banking system. At that time, the Chinese central government promoted the establishment of shareholding banks and increased the operation quality of the banking system. A series of reform policies were implemented to set up a market-oriented banking system.

[45] Levine (1997) summarizes some basic functions of the financial systems: to facilitate the trading, hedging, diversifying, and pooling of risk. These functions induce a natural conjecture stating that the development of the financial system in an economy may result in smaller output volatility by enhancing its ability to manage risks.

Although we think that a developed financial system could tame the growth volatility, although the recent financial crisis tells us another story.

An economy which focuses more on overseas trade is more likely to be affected by external shocks, and is more prone to experience higher growth volatility (Giovanni and Levchenko, 2009). On the other hand, a more open economy is capable of conducting international risk sharing to stabilize its economy, although the absolute size of the overseas investment from China is trivial before 2000.[46] As a result, trade openness may be positively linked with the growth volatility among Chinese provinces.

With the implementation of the "Nine-Year Compulsory Education" since the mid-1980s, China has experienced a substantial accumulation of human capital, which has positively affected the output and productivity growth (Fleisher, Li and Zhao, 2010). Here, we also conjecture that the accumulation of human capital may be an important factor for the output volatility of China. The possible channels through which education can influence the output volatility are as follows. First, more educated workers can develop their careers (e.g., less skilled workers are more likely to be unemployed when the economy goes into recession), resulting in less labor market volatility. Second, more educated people can have a better wealth plan to smooth their intertemporal consumption, thus contributing to the reduction of output volatility. Flug, Spilimbergo, and Wachtenheim (1998) reveal a significant negative link

[46] According to the data released by the Ministry of Commerce of China, the total stock of the overseas investment of Chinese enterprises amounted to only USD 29.9 billion in 2002 and reached USD 245.8 billion in 2009.

between volatility and investment in human capital, despite the causality direction.[47]

5 Data

To investigate the factors accounting for the volatility of China's economic growth, we use a provincial panel dataset covering 29 provinces over the reform period (1978–2008).[48] This dataset was mainly collected from the recently published *China Compendium of Statistics 1949–2009* and from the various issues of the *Chinese Statistical Yearbook*. In addition, several supplementary data sources are employed, including *Data of Gross Domestic Product of China 1952–1995, Data of Gross Domestic Product of China 1996–2002*, and *Data of Gross Domestic Product of China 1952–2004*. Data from the recently released publications are used and carefully cross-checked among different sources.[49]

The volatility of the economic growth of a province over a period is measured as the standard deviation of its real GDP growth. The factors potentially associated with the growth volatility include fiscal policy volatility, investment policy volatility, inflation volatility, initial GDP per capita, government size,

[47] Using second school enrolment as a human capital investment measure, Flug, Spilimbergo, and Wachtenheim (1998) argue that there is a negative link between volatility and human capital accumulation, which may be due to the detrimental effect of volatility on human capital investment. In this study, the average schooling years is used to measure human capital stock at time t, which is accumulated by human capital investment over the period prior to time t. Hence, we assume that the volatility at time t has no causal effect on the human capital stock at time t. Moreover, Flug, Spilimbergo, and Wachtenheim (1998) do not rule out the possibility of reversal causality of the relationship between volatility and human capital investment.

[48] Tibet and Chongqing are excluded in the dataset due to data unavailability.

[49] Significantly, the national account data of China and all provinces for the period 1993-2004 differ in various statistical publications since the Economic Census in 2004, which remarkably re-estimates national account data for this period. The main data source is *China Compendium of Statistics 1949-2009*. The national account data for 1993-2004 of all provinces are based on *Data of Gross Domestic Product of China 1952-2004*, those for 1978-1992 are from *Data of Gross Domestic Product of China 1952-1995*, and those after 2004 are from the *China Compendium of Statistics 1949-2009* and various issues of the *Chinese Statistical Yearbook*.

investment share, SOE reform, volatile age share, financial development, trade openness, human capital, and so on.

Consumer Price Index (CPI) is used as the measurement of inflation. In this work, we use the share of government consumption in the GDP to measure government size. The share of gross fixed capital formation in the GDP is employed as the proxy of investment share. To estimate the fiscal policy volatility and investment policy volatility, the real growth of government consumption is used to measure the government expenditure growth, whereas the real growth of gross fixed capital formation is adopted as investment growth. The fiscal policy volatility and investment policy volatility are then estimated according to Equations 1 and 10, respectively.

The process of SOE reform is represented by the share of SOEs in the total investment in fixed assets. We do not have much information about the age structure of employment for Chinese provinces. Alternatively, the volatile age share in the working age population is used. In this section, the volatile age groups are defined as those aged 15–29 and aged 55–64; we define the stable age group as those aged 30–54.

Other factors potentially affecting the growth volatility include financial development, trade openness, and human capital. Two traditional measures are employed in this study to represent the development of banking systems. The first one is the ratio of total deposit over the GDP, while the second one is the ratio of total loans over the GDP for each province. We use the share of total trade (export plus import) over the GDP as the measurement of provincial trade openness. A kind of human capital stock measure, i.e., the average schooling years of population aged 6 and above,[50] is employed to investigate its effect on Chinese provincial output volatility.

Next, we examine the effects of factors potentially associated with the volatility of China's economic growth. Cross-sectional and panel samples are used. The cross-sectional sample considers the period 1978–2008 as a whole. The output volatility, fiscal policy volatility, investment policy volatility, and inflation volatility are calculated over the whole sample period. Either the mean values or initial values of other control variables are used in the analysis, depending on different specifications. The panel sample divides the reform period into six 5-year consecutive non-overlapping sub-periods.[51] Therefore, the volatility, mean values, and initial values are calculated over each of the 5-year sub-periods. Here, we use a panel sample covering 29 provinces over 6 sub-periods.

6 Basic Results

6.1 Cross-Sectional Estimation

Firstly, we begin with a cross-province regression to link the different factors with the growth volatility, mainly focusing on the effects of policy volatilities. The general form of the regressions reported in Table 2 is as follows:

[50] We only have population census data from 1982, 1990 and 2000, and the population survey data from 1987, 1993, 1995–1999, and 2001–2008. The schooling years for the person holding primary school, junior high school, senior high school, and college and above as their final degree are calculated as 6, 9, 12 and 16 years, respectively. The schooling years of the illiterate population are given a value of 0. Subsequently, we calculate the average schooling years using the shares of population with different education attainments as weights. Finally, to fill the human capital data for the unavailable years, we obtain human capital panel data for the years 1978–2008 through linear interpolation. We then obtain human capital data for the years 1982–2008 through linear interpolation, after which we apply the growth rate of average schooling years for the period 1982–1987 to the growth rate of average schooling years for the period 1978–1982. Finally, we can obtain the human capital data for the whole reform period. The data sources of human capital estimation include the data of the third, fourth, and fifth China Population Census, the *China Statistical Yearbook* (1988–2008), the *China Population Statistical Yearbook* (1988–2006), and the *China Population and Employment Statistical Yearbook* (2007–2008).

[51] The year 2008 is included in the last sub-period.

$$\sigma_i^Y = \alpha + \beta' \Sigma_i + \gamma' X_i + \varepsilon_i , \quad (11)$$

where σ_i^Y is the growth volatility; Σ_i is a set of volatility variables, including fiscal policy volatility (σ_i^F), investment policy volatility (σ_i^I) and inflation volatility (σ_i^{CPI}); X_i is a set of control variables potentially associated with the growth volatility; ε_i is the residual term; and β and γ are the respective vectors of the coefficients.

The dependent variable (σ_i^Y) is the standard deviation of the real GDP growth for each Chinese provinces over the whole sample period. The key explanatory variables are fiscal policy volatility (σ_i^F) and investment policy volatility (σ_i^I), which are measured as the standard deviation of discretionary fiscal policy and undesired investment growth following Equations 1 and 10, respectively. Other important control variables are inflation volatility, initial real GDP per capita, government size, and investment share.

[TABLE 2 HERE]

The first two columns in Table 2 represent the unconditional relationship between growth volatility and policy volatilities. The t-values reported in the parentheses below the point estimates suggest that only the investment policy volatility is at the 1% significance level. We find an unconditional significant positive link between growth volatility and investment policy volatility. The third column shows the unconditional relationship between the inflation volatility and growth volatility, which turns out to be insignificant. Column 4 illustrates the relationship between the growth volatility and the three explanatory volatility variables. This indicates that only the investment policy volatility is still positively correlated with growth volatility, whereas the fiscal policy volatility and inflation volatility are insignificant.

Two control variables are added in the regression, as shown in the last two columns; we also employ the mean values of government size and investment share in Column 5. We can see that the investment policy volatility remains positive and significant, whereas the magnitude of its coefficient remains roughly stable. The government size is negatively and significantly correlated with growth volatility, suggesting the general role of fiscal policy as a stabilizer. The estimate of investment share is significant and positive, which implies that a province with higher investment share suffers higher volatility in the reform period.

Given that the average levels of the government size and investment share may be endogenous in the regression and affected by the growth volatility, we partly ruled out the reversal effect using the initial values of government size and investment share. Column 6 shows that the estimate of investment policy volatility remains significant and positive, whereas its magnitude increases. In addition, the initial government size is still negatively and significantly correlated with the growth volatility, despite the fact that the p-value increases from less than 5% to greater than 5%.

Table 2 shows a preliminary image of the relationship between growth volatility and its explanatory factors in the last three decades. Evidently, the investment policy volatility is significantly and positively associated with growth volatility. In addition, a higher government size is linked with a less volatile economic growth among Chinese provinces. On the other hand, fiscal policy volatility has no significant relationship with growth volatility.

However, our cross-province OLS regressions in Table 2 may be affected by several weak assumptions and suffer from endogeneity problems. First, although we use instrument variables to estimate the policy volatilities, it should still be our concern whether the policy volatilities (either σ_i^F or σ_i^I) are to some degree due to output volatility and not completely due to discretionary policies (Fatás and Mihov, 2003a). Second, policy volatilities and other control variables may suffer from the problems of simultaneity and endogeneity in the OLS regressions, since we cannot rule out the existence of dynamic effect and reversal effect of growth volatility to independent variables. Third, a trend of increasing stability of the Chinese economy is observed, and the unprecedented reform has changed China markedly over the last 30 years. Thus, we should take into account more time-series information in the analysis.

Therefore, in the following sections, we investigate the importance of different explanatory factors of growth volatility in a provincial panel sample. We not only discuss this issue in the context of time-varying volatility, but also GMM techniques to solve some problems related to simultaneity and endogeneity.

6.2 Panel Estimation

In this section, we divide the reform period (1978–2008) into six sub-periods, each with five consecutive non-overlapping years. A provincial panel sample covering 29 provinces for the six sub-periods is thus constructed. In the panel regressions, the volatility, mean value, and initial value are calculated over each sub-period for each province.

The panel regressions mainly follow the specification below:

$$\sigma_{i,t}^Y = \alpha + \beta'\Sigma_{i,t} + \gamma' X_{i,t} + \delta' PD_t + \varepsilon_{i,t}, \qquad (12)$$

where $\sigma_{i,t}^Y$ is the growth volatility; $\Sigma_{i,t}$ is a set of volatility variables, including fiscal policy volatility ($\sigma_{i,t}^F$), investment policy volatility($\sigma_{i,t}^I$) and inflation volatility ($\sigma_{i,t}^{CPI}$); $X_{i,t}$ is a set of control variables potentially associated with the growth volatility; $\varepsilon_{i,t}$ is the residual term, PD_t is a set of period dummies; and β, γ, and δ are the respective vectors of the coefficients. We have six non-overlapping consecutive sub-periods in the panel sample; hence, $t = 1,...,6$.

The dependent variable ($\sigma_{i,t}^{Y}$) is the standard deviation of the real GDP growth for each Chinese provinces over each sub-period *t*. The key explanatory variables are the fiscal policy volatility ($\sigma_{i,t}^{F}$) and investment policy volatility ($\sigma_{i,t}^{I}$), which are measured as the standard deviation of discretionary fiscal policy and undesired investment growth over each sub-period *t*, respectively. Other important control variables are inflation volatility, initial real GDP per capita, government size, and investment share.

Table 3 shows the regressions results using the provincial panel dataset. All regressions include period dummies as standard controls, and the details of dummies estimations are omitted for brevity.

Similar to the cross-provincial analysis, the first two columns report the link between growth volatility and discretionary policy volatility which is only conditional on period dummies. We find a significant and positive link between growth volatility and investment policy volatility, i.e., the estimate of investment policy volatility is significant at the 1% significance level. Columns 3 and 4 include the inflation volatility into the regression, demonstrating that the positive and significant relationship between growth volatility and investment policy volatility remains. Inflation volatility is also significantly and positively associated with growth volatility. The estimate of fiscal policy volatility is insignificant, the same with the one found in the cross-provincial analysis in Table 2.

We summarize the results in Columns 5 and 6 when some standard control variables enter the regression. Column 5 uses the mean values of government size and investment share, whereas Column 6 employs their initial values instead. Both columns reveal that the investment policy volatility remains positive, inflation volatility is positive, government size is negative, and investment share is positive. In addition, the first three estimates are highly significant at the 1% significance level.

The results of panel regressions in Table 3 confirm the main findings of the cross-provincial analyses shown in Table 2, i.e., a province with higher investment policy volatility is more likely to suffer a more volatile economic growth. The larger government size and smaller investment share are associated with lower growth volatility among Chinese provinces. The estimate of inflation volatility is, to some degree, different between cross-provincial and panel analyses.

[TABLE 3 HERE]

There are several potential factors affecting the results of panel regressions, e.g., the sample outliers and province size. We conduct several robustness tests to verify the basic results of Table 3. The results of robustness tests are summarized in Table 4. Columns 1 and 2 of Table 4 reproduce Columns 4 and 5 of Table 3 as benchmark specifications.

Columns 3 and 4 show the results of weighted regressions using the logarithm of the real GDP as regression weight. They indicate that the estimates of investment policy volatility, inflation volatility, government size, and investment share remain stable and significant. Moreover, the benchmark results in Columns 1 and 2 are not affected by the provincial GDP size.

We also consider the influences of sample outliers in Columns 5 and 6. Quantile regression, which is also known as the Least Absolute Value model, is employed to exclude the effect of sample outliers. In this section, the median is used as a measure of central tendency. Columns 5 and 6 demonstrate that even after controlling the effect of sample outliers, the investment policy volatility and inflation volatility are still positively and significantly associated with growth volatility. The government size remains negative and significant, but investment share lose its significance.

Finally, province-specific and time-invariant characteristics may not be fully captured by our control variables in benchmark specifications. As a result, we apply a provincial fixed-effect model to the panel sample. Columns 7 and 8 show the provincial fixed-effect regression result. As can be seen, only the investment policy volatility is highly significant, and other independent variables become insignificant after controlling the provincial fixed-effects, suggesting that inflation volatility, government size, and investment share are correlated with the provincial fixed-effect.

In all robustness tests, the investment policy volatility is significantly and positively associated with growth volatility. The estimate is highly significant at the 1% significance level, and the coefficient magnitude is roughly stable. This constitutes the main finding of the panel sample analysis, i.e., a province with investment policy volatility is prone to experience more volatile economic growth.

[TABLE 4 HERE]

Certainly, there is still a pronounced issue that investment policy volatility may be induced by growth volatility to some extent, although economic growth has already been instrumented in the estimation shown in Equation 10.

Furthermore, with the presence of dynamic effects and simultancity, the OLS estimations in Table 3 and Table 4 may be biased and inconsistent. The following steps in the next section employ an econometric technique to solve these problems.

6.3 GMM Estimation

As stated previously, we cannot rule out the possibility that the undesired investment growth may partly reflect the effect of economic growth. Moreover, growth volatility and two policy volatilities may be simultaneously determined by the same factors and shocks as well as some explanatory factors. For instance, government size and investment share may be affected by the growth volatility. As a result, we have to take into account both the dynamic and endogeneity effects in estimating the determinants of growth volatility.

Arellano and Bond (1991), Arellano and Bover (1995), and Blundell and Bond (1998) develop the first-difference GMM approach and system GMM techniques to solve these problems. Furthermore, Blundell and Bond (2000) and Bond (2002) argue that the first-difference GMM approach may be biased in the case of weak instruments and finite samples, which is the very case of our study. The provincial panel dataset used in the previous section has a finite sample with many provinces but with few sub-periods. Therefore, we use the system GMM approach to solve the simultancity and endogeneity problem of our OLS regressions. Here, either the one-step or the two-step approach of system GMM estimation can be used. Usually, both of them are reported because there is a downward bias in the computed standard errors in the two-step estimation. However, with the finite sample correction of Windmeijer (2005), the standard errors in the two-step estimation are quite accurate, and the two-step estimation with this correction seems to be modestly superior to cluster-robust one-step estimation. Therefore, the two-step system GMM estimation is our main focus. The first-difference GMM and one-step system GMM estimations are also employed as reference results in this section.

In the system GMM approach of Blundell and Bond (1998), the instruments for regression in levels are the lagged differences of the corresponding variables, while those for regression in differences are the lagged levels. Two tests are usually employed to verify the validity of the instruments. The first one is the Sargan over-identifying test, which examines the overall validity of instruments. In addition, Hansen's over-identification test can also be used to verify the validity of instruments. Both of them are reported in this section. The second one is the Arellano-Bond autoregressive (AR) test, which is used to examine the presence of second-order serial correlation in the first-difference error term. The AR tests allow the difference error term to be first-order serially correlated, but the second-order serial correlation may violate the basic assumption of GMM approach.

Columns 1 and 2 in Table 5 reproduce the results of OLS and fixed-effect specifications in Table 4. Other columns report the GMM estimation results. We employ three GMM approaches, namely, the first-difference GMM (D-GMM), one-step system GMM (S-GMM1) and two-step system GMM (S-GMM2), for results cross-checking. In this essay, the small-sample correction to the covariance matrix estimate is applied to all GMM estimations. In the one-step system GMM estimation, we report the cluster-robust standard errors, which are robust to the heteroskedasticity and arbitrary patterns of the autocorrelation within provinces. In the two-step system GMM estimation, the finite sample correction of Windmeijer (2005) is made to the covariance matrix. We then conduct Sargan and Hansen's over-identification test to verify the validity of instruments, and Arellano-Bond AR tests to examine the serial correlation of the residuals. The Sargan and Hansen's test results in Columns 3 to 8 suggest that there is no evidence rejecting the validity of instrument variables. The test statistics of Arellano-Bond AR tests suggest that we can reject the null of no first-order serial correlation, but we cannot reject the null of no second-order serial correlation. Therefore, test statistics in all GMM estimations imply the correct use of instruments and GMM estimations.

First, we treat the policy volatilities and inflation volatility as endogenous variables, the initial GDP per capita as exogenous variables, and the mean values of government size and investment share as pre-determined variables. All period dummies are treated as exogenous variables. Columns 3 to 5 summarize the results of GMM estimations under the assumptions above. We take Column 5 as our primary result. After taking into account the simultaneity and endogeneity problem of policy volatilities and inflation volatility, the two-step system GMM estimation shows that the investment policy volatility positively and significantly affects the growth volatility at the 5% significance level. Inflation volatility loses its significance to some degree in Column 5, perhaps because inflation and growth are concurrent issues for an economy. The government size has negative influence on growth volatility, suggesting the counter-cyclical role of government expenditure.

Columns 3 and 4 report the difference and one-step system GMM estimation, respectively. In both columns, it can be seen that higher investment policy volatility results in higher growth volatility, whereas the government size has a detrimental effect on growth volatility. Unlike the result in Column 5, inflation volatility and investment share significantly promote the growth volatility.

[TABLE 5 HERE]

In Columns 3 to 5, the average levels of government size and investment share are considered not fully exogenous but pre-determined. However, the government may be affected by growth volatility, since a province with higher volatility is more prone to expand its government expenditure to stabilize its economy (Rodrik, 1998). Moreover, the investment share may also be influenced by growth volatility, not because of the uncertainty concern but positively due to the high-risk-high-return nexus. Therefore, we relax the assumption about the mean values of government size and investment share, and assume that they are endogenous. Columns 6 to 8 represent the GMM estimation results under such assumptions.

Meanwhile, the results of the two-step system GMM estimation are shown in Column 8. As can be seen, the investment policy volatility remains positive and significant despite a slight increase in the p-value. The government size becomes highly significant with negative effect on output volatility, whereas the investment share seems to have lost its significance. Looking at the difference GMM and one-step system GMM estimations in Columns 6 and 7, we also find a significant and positive effect of investment policy volatility on growth volatility. The signs of other explanatory factors are the same as those in Column 8, although they vary in terms of significance level.

According to the analyses above, the most prominent result is that investment policy volatility amplifies growth volatility, while fiscal policy volatility does not. Higher government size and lower investment shares are likely to result in lower growth volatility, although the estimates are not always significant when different estimation approaches are used. In this section, we may say that the investment policy volatility accounts for a significant part of the growth volatility. Hence, the decline of investment policy volatility greatly contributes to the increasing stability of the Chinese economy.

7 Robustness Tests

We consider Column 8 in Table 5 as the benchmark estimation results of the effects of different explanatory factors on growth volatility. In this section, we test the robustness of our main results, first by including other potentially important factors into the regression; second, by using initial values of government size and investment share instead of their mean values; and finally, by employing alternative estimation specifications of policy volatilities.

7.1 Additional Controls

In the discussions presented in Section 4, the SOE reform, volatile age share, financial development, trade openness, and human capital are factors that are considered to be potentially linked to growth volatility. Table 6 shows the results of robustness tests with these additional control variables. In this section, we consider the two-step system GMM estimates in Column 8 of Table 5 as the benchmark results in which government size and investment share are treated as endogenous variables. Column 1 of Table 6 reproduces the benchmark results, and the other columns show the results of the two-step system GMM estimates with additional control variables. We use the mean values of all additional variables in the robustness tests, and consider each one of them as an endogenous variable, except for the stable age share. The stable age share in the working-age population is mostly determined by fertility choice that occurred more than 20 years ago; thus, it should be considered to be exogenous.

[TABLE 6 HERE]

With each of the additional control variables, the positive effect of investment policy volatility on growth volatility remains significant in most cases. In several columns, the significance level increases to better than 1% (see Columns 4). In most cases of the robustness tests, government size and investment share have the same sign with the benchmark specification, despite the difference in significance level. No additional control variable is significant in Table 6. The results of Sargan and Hansen's over-identification tests and the Arellano-Bond AR tests suggest that all specifications in Table 6 satisfy the assumptions of GMM estimation. According to the results in Table 6, our benchmark results for the two-step GMM estimation are robust to the inclusion of additional variables, including the trade openness, provincial GDP size, human capital, SOE reform, financial development, and volatile age share. In addition, none of the additional control variables have significant effects on growth volatility.

7.2 Initial Values of Controls

In the benchmark specifications shown in Tables 4 and 5, we use the mean values of government size and investment share as standard controls. Furthermore, these two variables are considered endogenous in GMM estimations and in subsequent robustness tests with additional variables. We use the initial values of these two control variables to conduct robustness tests. Using the initial values may, to some degree, reduce the endogeneity problems in OLS specifications. Moreover, in GMM estimations, we treat initial values as exogenous or pre-determined, so that the total number of instrument variables can be reduced.

[TABLE 7 HERE]

We summarize the results with initial values of government size and investment share as control variables in Table 7. Columns 1 to 4 show the results of OLS, weighted OLS, Quantile and fixed-effect regressions, respectively. Columns 5 to 7 show the results of the three GMM approaches with assumption that the initial values of government size and investment share are exogenous. We treat these two variables to be pre-determined and summarize the estimation results. These are shown in Columns 8 to 10.

The first four columns illustrate similar results as those shown in Table 4. Based on the initial values of government size and investment share as control variables, investment policy volatility is positively and significantly associated with growth volatility. In addition, coefficient estimates are close to those in Table 4, in which we use the mean values as control variables. Moreover, government size and investment share are significantly linked with growth volatility with different directions. Inflation volatility is also positively and significantly correlated with growth volatility.

Furthermore, we employ the GMM approaches to estimate the determinants of growth volatility. First, the initial values of government size and investment share are considered exogenous. Columns 5 to 7 indicate that the investment policy volatility has a positive effect on growth volatility, and the coefficient increases a bit compared with the estimates in Columns 1 to 4. Subsequently, we relax the assumption of exogenous initial conditions of government size and investment share, and treat them as being pre-determined. We find from Columns 8 to 10 that higher investment policy volatility results in higher growth volatility. Despite the weak significance levels in two-step system GMM estimations, we can reach the consistent conclusion that by using initial conditions of government size and investment share as control variables, reduction in investment policy volatility can lead to an increasingly stable economic growth in China. Moreover, the increase of government size may also greatly contribute to the decline of growth volatility in China.

7.3 Alternative Specifications of Discretionary Policy

One may suspect that our conclusion on the important role of investment policy volatility highly depends on the estimation method of the policy volatility. In the following discussions, we examine the robustness of our main results to different estimation specifications.

For the fiscal policy volatility, we substitute the lagged level of the real government expenditure used in Equation 1 with the lagged growth of the real government expenditure, following Equation 13. Real GDP growth is also instrumented by its lagged value and lagged inflation. Rather than specifying inflation and inflation square as the only control variables in Equation 10, we also incorporate the lagged real investment growth into the specification to estimate the undesired investment growth, as shown in Equation 14. Real economic growth and capital input cost are instrumented by their lagged values and lagged inflation. In both Equations 13 and 14, inflation and inflation square are included in X_t.

$$\Delta \ln G_t = \alpha + \beta \Delta \ln G_{t-1} + \gamma \Delta \ln Y_t + \phi X_t + \varepsilon_t^{F'}, \qquad (13)$$

$$\Delta \ln I_t = \alpha + \beta \Delta \ln Y_t + \gamma \Delta \ln i_t + \eta \Delta \ln I_{t-1} + \phi X_t + \varepsilon_t^{I'}, \qquad (14)$$

where the notations in Equations 13 and 14 are the same as those shown in Equations 1 and 10.

Using the alternative estimation specifications of Equations 13 and 14, we can obtain discretionary fiscal policy ($\varepsilon_{i,t}^{G'}$) and undesired investment growth ($\varepsilon_{i,t}^{I'}$).

Their standard deviations are calculated to measure the fiscal policy volatility and investment policy volatility, respectively. The main results using alternative estimation method are shown in Table 8.

[TABLE 8 HERE]

Columns 1 to 4 show the results of OLS, weighted OLS, Quantile and fixed-effect regressions, respectively. Columns 5 to 7 present the results of GMM estimations considering the mean value of government size and investment share as pre-determined variables. Columns 8 to 10 summarize the GMM estimates by treating the mean values of government size and investment share to be endogenous. The three GMM estimation methods are employed just like in the benchmark results. All GMM estimations pass the Sargan and Hansen's over-identification tests and Arellano-Bond AR tests for serial correlation, suggesting the validity of our specifications.

We can find in Table 8 that, using different calculation specifications of discretionary policy, the positive effect of investment policy volatility on growth volatility in China remains significant and that its magnitude is relatively stable. Inflation volatility plays a positive role in explaining the growth volatility, though not always significant. Moreover, government size and investment share affect the growth volatility in the same direction with the benchmark results, although they vary in terms of significance level.

Moreover, we also conduct the robustness tests of our benchmark results to other different estimation specifications of policy volatility. The first specification includes both the lagged value of investment growth and the lagged value of real investment in the estimation specification of undesired investment growth shown in Equation 10. The second one uses OLS rather than IV and 2SLS methods to estimate the undesired investment growth.[52] Furthermore, two different treatments of government size and investment share are considered. One uses their mean values and includes them into the regression either as pre-determined or endogenous variables. The other one includes their initial values either as exogenous or pre-determined variables.

The results of all robustness tests lead to virtually consistent qualitative conclusion that the investment policy volatility significantly amplifies growth volatility. On the other hand, fiscal policy volatility has no significant effect on growth volatility. For brevity, the details of the results are not reported here. However, they can be made available upon request.

8 Conclusions

This study documents a significant decline in the growth volatility of Chinese provinces over the last three decades. The key conclusion of this essay is that investment policy volatility accounts for a significant part of the volatility of China's economic growth. A province with higher investment policy volatility, which is measured as the standard deviation of undesired investment growth, is likely to suffer higher growth volatility. The less aggressive use of investment policies to promote undesired investment growth as well as a more effective and market-driven macro-control policies can lead to the increasing stability of the economic growth of Chinese provinces in the reform period.

The discretionary policy is the policy component, which deviates from the current macroeconomic conditions and represents the cyclically adjusted policy stance of local governments (or local economies). Policy volatility is defined as the standard deviation of discretionary policy, and is considered a measure of

[52] We also re-estimate the discretionary fiscal policy using the similar specification as that used in the discretionary investment policy.

the aggressiveness of using discretionary policy. Cross-country studies have shown that the discretion in fiscal policy can harm macroeconomic stability (Fatás and Mihov, 2003a). In the context of the Chinese economy, we introduce investment policy volatility, following the definitions of discretionary fiscal policy and fiscal policy volatility. Investment policy volatility is measured as the standard deviation of undesired investment growth, which is calculated as the difference between the actual and desired investment growth. We find that both the fiscal policy volatility and investment policy volatility have declined substantially in recent decades.

OLS regressions reveal a significant and positive relationship between investment policy volatility and growth volatility. However, the discretionary fiscal policy and undesired investment growth may be simultaneously determined by the same factors, together with economic growth, or they cannot fully remove the influence of current macroeconomic conditions. Therefore, endogeneity and simultaneity bias may emerge. In this essay, we use the GMM approaches to estimate the effect of policy volatility on output volatility, so that the dynamic effects and endogeneity problem can be solved as much as possible. The estimation results show that, in China, only investment policy volatility significantly and positively affects growth volatility, whereas the effect of fiscal policy volatility is insignificant. This finding is robust to the inclusion of additional control variables, substitution of initial conditions for mean values of standard controls, and alternative specifications of policy volatility. Aside from the prominent positive effects of investment policy volatility, we also discover the stabilizing role of government expenditure and the positive effect of investment share on growth volatility, although they are not always significant in different specifications. This study concludes that a better institutional environment, stemming from stable and predictable policies of local governments and benign inter-actions between the government and market, is crucial in ensuring the macroeconomic stability of the Chinese economy.

We find a significant role of investment policy volatility in accounting for the aggregate output volatility. It suggests that the distortions of investment policies arising from the investment hunger of local governments and imperfect macro control implementations of the central government are detrimental to the macro stability of the Chinese economy. Along with the shift of development strategy of the Chinese government from focusing on high growth rate to emphasizing growth sustainability, and more market-driven macroeconomic policy instruments being employed, the Chinese economy has become more stable after the early 1990s. However, it is noteworthy that the investment share in GDP is increasing in recent years, and local governments are recommencing their investment enthusiasm in the aftermath of recent global financial crisis. How to contain the investment hunger and enhance the growth sustainability without increasing fluctuation of undesired investment growth should be paid serious attention since investment policy volatility could damper the stability of the macro economy.

References

[1] Alesina, A., Ardagna, S., Perotti, R. and Schiantarelli, F. (2002). Fiscal Policy, Profits, and Investment. *The American Economic Review* 92(3): 571-589.

[2] Alesina, A., Perotti, R., Giavazzi, F. and Tryphon, K. (1995). Fiscal Expansions and Adjustments in OECD Countries. *Economic Policy* 10(21): 207-248.

[3] Andres, J., Domenech, R. and Fatás, A. (2008). The Stabilizing Role of Government Size. *Journal of Economic Dynamics and Control* 32(2): 571-593.

[4] Arellano, M. and Bond, S. (1991). Some Tests of Specification for Panel Data: Monte Carlo Evidence and An Application to Employment Equations. *Review of Economic Studies* 58(2): 277-297.

[5] Arellano, M. and Bover, O. (1995). Another Look at the Instrumental Variable Estimation of Error-components Models. *Journal of Econometrics* 68(1): 29-51.

[6] Bai, C.-E., Lu, J. and Tao, Z. (2006). The Multitask Theory of State Enterprise Reform: Empirical Evidence from China. *American Economic Review* 96(2): 353-353.

[7] Bai, C.-E., Lu, J., Tao, Z. and Wang, Y. (2000). A Multitask Theory of State Enterprise Reform. *Journal of Comparative Economics* 28(4): 716-738.

[8] Barlevy, G. (2004). The Cost of Business Cycles under Endogenous Growth. *American Economic Review* 94(4): 964-990.

[9] Barro, R. J. (1991). Economic Growth in a Cross Section of Countries. *Quarterly Journal of Economics* 106(2): 407-443.

[10] Beck, T., Lundberg, M. and Majnoni, G. (2006). Financial Intermediary Development and Growth Volatility: Do Intermediaries Dampen or Magnify Shocks? *Journal of International Money and Finance* 25(7): 1146-1167.

[11] Blundell, R. and Bond, S. (1998). Initial Conditions and Moment Restrictions in Dynamic Panel Data Models. *Journal of Econometrics* 87(1): 115-143.

[12] Blundell, R. and Bond, S. (2000). GMM Estimation with Persistent Panel Data: An Application to Production Functions. *Econometric Reviews* 19(3): 321-340.

[13] Boivin, J. and Giannoni, M. P. (2006). Has Monetary Policy Become More Effective? *Review of Economics and Statistics* 88(3): 445-462.

[14] Bond, S. R. (2002). Dynamic Panel Data Models: A Guide to Micro Data Methods and Practice. *Portuguese Economic Journal* 1(2): 141-162.

[15] Bosworth, B. and Collins, S. M. (2008). Accounting for Growth: Comparing China and India. *Journal of Economic Perspectives* 22(1): 45-66.
[16] Brandt, L. and Zhu, X. (2000). Redistribution in a Decentralized Economy: Growth and Inflation in China under Reform. *Journal of Political Economy* 108(2): 422-439.
[17] Brandt, L. and Zhu, X. (2001). Soft Budget Constraint and Inflation Cycles: A Positive Model of the Macro-Dynamics in China during Transition. *Journal of Development Economics* 64(2): 437-457.
[18] Brandt, L. and Zhu, X. (2010). Accounting for China's Growth. *IZA Discussion Papers.*
[19] Caballero, R. J., Engel, E. M. R. A. and Haltiwanger, J. C. (1995). Plant-Level Adjustment and Aggregate Investment Dynamics. *Brookings Papers on Economic Activity* 26(2): 1-54.
[20] Candelon, B., Muysken, J. and Vermeulen, R. (2010). Fiscal Policy and Monetary Integration in Europe: An Update. *Oxford Economic Papers* 62(2): 323-349.
[21] Chow, G. C. (2010). Note on a Model of Chinese National Income Determination. *Economics Letters* 106(3): 195-196.
[22] Davis, S. J. and Kahn, J. A. (2008). Interpreting the Great Moderation: Changes in the Volatility of Economic Activity at the Macro and Micro Levels. *Journal of Economic Perspectives* 22(4): 155-180.
[23] Dynan, K. E., Elmendorf, D. W. and Sichel, D. E. (2006). Can Financial Innovation Help to Explain the Reduced Volatility of Economic Activity? *Journal of Monetary Economics* 53(1): 123-150.
[24] Fatás, A. and Mihov, I. (2001). Government Size and Automatic Stabilizers: International and Intranational Evidence. *Journal of International Economics* 55(1): 3-28.
[25] Fatás, A. and Mihov, I. (2003a). The Case for Restricting Fiscal Policy Discretion. *Quarterly Journal of Economics* 118(4): 1419-1447.
[26] Fatás, A. and Mihov, I. (2003b). On Constraining Fiscal Policy Discretion in EMU. *Oxford Review of Economic Policy* 19(1): 112-131.
[27] Fatás, A. and Mihov, I. (2006). The Macroeconomic Effects of Fiscal Rules in the US States. *Journal of Public Economics* 90(1-2): 101-117.
[28] Fleisher, B. M., Li, H. and Zhao, M. Q. (2010). Human Capital, Economic Growth, and Regional Inequality in China. *Journal of Development Economics* 92(2): 215-231.
[29] Flug, K., Spilimbergo, A. and Wachtenheim, E. (1998). Investment in Education: Do Economic Volatility and Credit Constraints Matter? *Journal of Development Economics* 55(2): 465-481.

[30] Galí, J. and Perotti, R. (2003). Fiscal Policy and Monetary Integration in Europe. *Economic Policy* 18(37): 533-572.

[31] Gao, X. (2007). Business Cycle Accounting for the Chinese Economy. *MPRA Paper*.

[32] Giovanni, J. and Levchenko, A. A. (2009). Trade Openness and Volatility. *Review of Economics and Statistics* 91(3): 558-585.

[33] He, L. (2008). Has Fiscal Federalism Worker for Macroeconomic Purposes? The Chinese Experience 1994-2003. *China and World Economy* 16(1): 17-33.

[34] He, Q., Chong, T.-L. T. and Shi, K. (2009). What Accounts for Chinese Business Cycle? *China Economic Review* 20(4): 650-661.

[35] Jaimovich, N. and Siu, H. E. (2009). The Young, the Old, and the Restless: Demographics and Business Cycle Volatility. *American Economic Review* 99(3): 804-826.

[36] Jefferson, G. H. and Su, J. (2006). Privatization and Restructuring in China: Evidence from Shareholding Ownership, 1995-2001. *Journal of Comparative Economics* 34(1): 146-166.

[37] Kose, M. A., Prasad, E. S. and Terrones, M. E. (2006). How Do Trade and Financial Integration Affect the Relationship between Growth and Volatility? *Journal of International Economics* 69(1): 176-202.

[38] Levinson, A. (1998). Balanced Budgets and Business Cycles: Evidence from the States. *National Tax Journal* 51(4): 715-732.

[39] Li, H. and Zhang, J. (2007). Do High Birth Rates Hamper Economic Growth? *Review of Economics and Statistics* 89(1): 110-117.

[40] Li, H. and Zhou, L. (2005). Political Turnover and Economic Performance: The Incentive Role of Personnel Control in China. *Journal of Public Economics* 89(9-10): 1743-1762.

[41] Lin, J. Y., Cai, F. and Li, Z. (1998). Competition, Policy Burdens, and State-Owned Enterprise Reform. *American Economic Review* 88(2): 422-427.

[42] Lin, J. Y. and Tan, G. (1999). Policy Burdens, Accountability, and the Soft Budget Constraint. *American Economic Review* 89(2): 426-431.

[43] Lucas, R. E. (2003). Macroeconomic Priorities. *American Economic Review* 93(1): 1-14.

[44] Michael, B. (2004). Chinese Macroeconomic Stabilisation and Reform: A Briefing Note. *China and World Economy* 12(3): 61-69.

[45] Naughton, B. J. (1995a). China's Macroeconomy in Transition. *China Quarterly*(144): 1083-1104.

[46] Naughton, B. J. (1995b). *Growing Out of the Plan: Chinese Economic Reform, 1978-1993*. New York, Cambridge University Press.

[47] Pallage, S. and Robe, M. A. (2003). On the Welfare Cost of Economic Fluctuations in Developing Countries. *International Economic Review* 44(2): 677-698.

[48] Prasad, E. S. (2009). Is the Chinese Growth Miracle Built to Last? *China Economic Review* 20(1): 103-123.

[49] Prasad, E. S. and Rajan, R. G. (2006). Modernizing China's Growth Paradigm. *American Economic Review* 96(2): 331-336.

[50] Qin, D. and Song, H. (2009). Sources of Investment Inefficiency: The Case of Fixed-Asset Investment in China. *Journal of Development Economics* 90(1): 94-105.

[51] Rodrik, D. (1998). Why Do More Open Economies Have Bigger Governments. *Journal of Political Economy* 106(5): 997-1032.

[52] Song, H., Liu, Z. and Jiang, P. (2001). Analysing the Determinants of China's Aggregate Investment in the Reform Period. *China Economic Review* 12(2-3): 227-242.

[53] Stock, J. H. and Watson, M. W. (2002). Has the Business Cycle Changed and Why? *NBER Macroeconomics Annual* 17: 159-218.

[54] Windmeijer, F. (2005). A Finite Sample Correction for the Variance of Linear Efficient Two-Step GMM Estimators. *Journal of Econometrics* 126(1): 25-51.

[55] Yao, Y. (2005). Chinese Privatization: Causes and Outcomes. *China and World Economy* 13(1): 66-80.

[56] Young, A. (1995). The Tyranny of Numbers: Confronting the Statistical Realities of the East Asian Growth Experience. *Quarterly Journal of Economics* 110(3): 641-680.

[57] Young, A. (2003). Gold into Base Metals: Productivity Growth in the People's Republic of China During the Reform Period. *Journal of Political Economy* 111(6): 1220-1261.

[58] Yu, Q. (1997). Economic Fluctuation, Macro Control, and Monetary Policy in the Transitional Chinese Economy. *Journal of Comparative Economics* 25(2): 180-195.

[59] Yusuf, S. (1994). China's Macroeconomic Performance and Management During Transition. *Journal of Economic Perspectives* 8(2): 71-92.

[60] Zhang, N. (2011). Has the Chinese Economy Become Less Volatile? Structural Break Detection and Volatility Decomposition. *mimeo*. Department of Economics, Chinese University of Hong Kong.

Tables and Figures

Table 1: Volatility Comparison of Two Sub-periods

	1978-1992	1993-2008	Change		1978-1992	1993-2008	Change
Beijing	4.75	1.56	-3.19 **	Hubei	5.14	2.18	-2.96 ***
Tianjin	4.31	2.13	-2.18 *	Hunan	2.53	1.8	-0.73
Hebei	4.55	2.43	-2.11 ***	Guangdong	4.78	3.59	-1.19 *
Shanxi	5.75	2.28	-3.46 ***	Guangxi	4.31	3.1	-1.21
Inner Mongolia	4.93	4.55	-0.38	Hainan	9.74	3.89	-5.85 **
Liaoning	5.46	2.5	-2.96 ***	Chongqing	3.42	2.39	-1.03
Jilin	6.43	2.64	-3.79 ***	Sichuan	3.13	2	-1.13 *
Heilongjiang	2.4	1.63	-0.77	Guizhou	4.52	1.63	-2.90 ***
Shanghai	3.5	1.77	-1.73 *	Yunnan	4.12	1.89	-2.24 ***
Jiangsu	6.2	2.64	-3.56 **	Tibet	10.31	1.98	-8.32 ***
Zhejiang	6.34	3.52	-2.82 *	Shaanxi	5.35	1.78	-3.56 ***
Anhui	6.39	2.82	-3.57 ***	Gansu	6.04	1.06	-4.99 ***
Fujian	5.26	3.8	-1.45 **	Qinghai	6.75	1.86	-4.89 ***
Jiangxi	4.23	2.47	-1.76 **	Ningxia	4.43	1.61	-2.82 **
Shandong	4.46	2.8	-1.66 **	Xinjiang	3.02	1.81	-1.21 *
Henan	5.61	2.6	-3.01 **				

Note: Significance levels of standard deviation change are from Levene's robust test for the equality of variances of the two sub-periods. ***, ** and * represent significance at the 1%, 5% and 10% level respectively.

Table 2: Cross-province OLS Estimation Results

VARIABLES	(1) OLS1	(2) OLS2	(3) OLS3	(4) OLS4	(5) OLS5	(6) OLS6
Fiscal Policy Volatility	0.00981			-0.00765	-0.000565	-0.0305
	(0.0455)			(0.0446)	(0.0347)	(0.0436)
Investment Policy Volatility		0.0337***		0.0350**	0.0376**	0.0479**
		(0.0101)		(0.0163)	(0.0150)	(0.0172)
Inflation Volatility			0.421	0.381	0.408	0.376
			(0.448)	(0.476)	(0.352)	(0.504)
Initial GDP per capita					-0.567*	-0.187
					(0.275)	(0.249)
Government Size					-0.164**	
					(0.0598)	
Investment Share					0.0855**	
					(0.0332)	
Initial Government Size						-0.0857*
						(0.0474)
Initial Investment Share						0.0163
						(0.0197)
Constant	3.635***	3.270***	1.112	0.957	3.176	2.535
	(0.474)	(0.217)	(2.780)	(3.033)	(2.994)	(4.084)
Observations	29	29	29	29	29	29
R-squared	0.003	0.121	0.071	0.188	0.428	0.267

Note: Dependent variable is growth volatility measured as the standard deviation of GDP growth over a period. Robust standard errors are in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 3: Panel OLS Estimation Results

VARIABLES	(1) OLS1	(2) OLS2	(3) OLS3	(4) OLS4	(5) OLS5	(6) OLS6
Fiscal Policy Volatility	0.0106			-0.00868	-0.0153	-0.0210
	(0.0268)			(0.0237)	(0.0221)	(0.0230)
Investment Policy Volatility		0.0409***		0.0456***	0.0493***	0.0518***
		(0.0123)		(0.0134)	(0.0127)	(0.0125)
Inflation Volatility			0.339**	0.371**	0.376***	0.372***
			(0.165)	(0.153)	(0.136)	(0.140)
Initial GDP per capita					-0.0973	-0.0545
					(0.183)	(0.174)
Government Size					-0.102***	
					(0.0380)	
Investment Share					0.0406**	
					(0.0200)	
Initial Government Size						-0.102***
						(0.0365)
Initial Investment Share						0.0316*
						(0.0172)
Constant	4.822***	4.125***	4.194***	3.294***	3.662**	3.495**
	(0.512)	(0.388)	(0.576)	(0.579)	(1.608)	(1.645)
Observations	174	174	174	174	174	174
R-squared	0.548	0.582	0.573	0.614	0.641	0.638

Note: Dependent variable is growth volatility measured as the standard deviation of GDP growth over a period. Period dummies are controlled in regression. Robust standard errors are in parentheses. ***, ** and * represent $p<0.01$, $p<0.05$ and $p<0.1$, respectively.

Table 4: Robustness Tests of Panel OLS Estimation Results

VARIABLES	(1) OLS1	(2) OLS2	(3) WT1	(4) WT2	(5) Quantile1	(6) Quantile2	(7) FE1	(8) FE2
Fiscal Policy Volatility	-0.00868	-0.0153	-0.0128	-0.0179	-0.0135	-0.0199	0.0163	0.0142
	(0.0237)	(0.0221)	(0.0208)	(0.0198)	(0.0122)	(0.0134)	(0.0266)	(0.0280)
Investment Policy Volatility	0.0456***	0.0493***	0.0431***	0.0469***	0.0475***	0.0510***	0.0502**	0.0477***
	(0.0134)	(0.0127)	(0.0118)	(0.0114)	(0.00771)	(0.00810)	(0.0205)	(0.0170)
Inflation Volatility	0.371**	0.376***	0.332**	0.348***	0.268***	0.276***	0.254	0.239
	(0.153)	(0.136)	(0.133)	(0.124)	(0.0699)	(0.0719)	(0.161)	(0.145)
Initial GDP per capita		-0.0973		-0.0457		0.0781		0.869
		(0.183)		(0.167)		(0.172)		(0.719)
Government Size		-0.102***		-0.0903**		-0.0540**		0.00958
		(0.0380)		(0.0350)		(0.0262)		(0.0512)
Investment Share		0.0406**		0.0336**		0.00322		0.0479*
		(0.0200)		(0.0166)		(0.0115)		(0.0244)
Constant	3.294***	3.662**	3.382***	3.451**	2.921***	2.878**	3.098***	-4.526
	(0.579)	(1.608)	(0.510)	(1.430)	(0.341)	(1.314)	(0.547)	(5.555)
Observations	174	174	174	174	174	174	174	174
R-squared	0.614	0.641	0.633	0.655			0.659	0.675
Number of Provinces							29	29

Note: Dependent variable is growth volatility measured as the standard deviation of GDP growth over a period. Period dummies are controlled in regression. Robust standard errors are in parentheses. ***, ** and * represent p<0.01, p<0.05 and p<0.1, respectively.

Table 5: Panel GMM Estimation Results

VARIABLES	(1) OLS	(2) FE	(3) D-GMM	(4) S-GMM1	(5) S-GMM2	(6) D-GMM	(7) S-GMM1	(8) S-GMM2
Fiscal Policy Volatility	-0.0153	0.0142	-0.000585	-0.0282	-0.0440	-0.0113	-0.0442*	-0.0317
	(0.0221)	(0.0280)	(0.0473)	(0.0259)	(0.0415)	(0.0381)	(0.0240)	(0.0520)
Investment Policy Volatility	0.0493***	0.0477***	0.0487*	0.0547**	0.0516**	0.0565***	0.0641***	0.0511*
	(0.0127)	(0.0170)	(0.0242)	(0.0234)	(0.0208)	(0.0173)	(0.0187)	(0.0250)
Inflation Volatility	0.376***	0.239	0.609***	0.479***	0.681*	0.575**	0.643***	0.743*
	(0.136)	(0.145)	(0.206)	(0.155)	(0.376)	(0.221)	(0.169)	(0.389)
Initial GDP per capita	-0.0973	0.869	2.872	-0.0260	0.255	0.548	0.0478	0.290
	(0.183)	(0.719)	(1.903)	(0.222)	(0.491)	(1.922)	(0.223)	(0.987)
Government Size	-0.102***	0.00958	-0.0542	-0.100**	-0.0636	-0.0253	-0.108***	-0.154***
	(0.0380)	(0.0512)	(0.0738)	(0.0417)	(0.0726)	(0.0579)	(0.0354)	(0.0468)
Investment Share	0.0406**	0.0479*	0.0557*	0.0419**	0.0228	0.0529	0.0365*	0.0446
	(0.0200)	(0.0244)	(0.0307)	(0.0187)	(0.0375)	(0.0349)	(0.0191)	(0.0437)
Constant	3.662**	-4.526		2.940*	0.855		2.325	0.703
	(1.608)	(5.555)		(1.645)	(3.966)		(1.524)	(6.882)
Observations	174	174	145	174	174	145	174	174
R-squared	0.641	0.675						
Number of Provinces		29	29	29	29	29	29	29
Arellano-Bond AR(1) Test			0.0122	0.0144	0.0179	0.00796	0.00775	0.0122
Arellano-Bond AR(2) Test			0.764	0.339	0.835	0.605	0.740	0.740
Sargan Over-ID Test			0.969	0.845	0.845	0.942	0.987	0.987
Hansen Over-ID Test			1.000	1.000	1.000	0.952	1.000	1.000

Note: Dependent variable is growth volatility measured as the standard deviation of GDP growth over a period. Period dummies are controlled in regression. Robust standard errors are in parentheses. ***, ** and * represent $p<0.01$, $p<0.05$ and $p<0.1$, respectively.

Table 6: Robustness Tests of Panel GMM Estimation Results with Additional Controls

VARIABLES	(1) S-GMM2	(2) S-GMM2	(3) S-GMM2	(4) S-GMM2	(5) S-GMM2	(6) S-GMM2	(7) S-GMM2	(8) S-GMM2
Fiscal Policy Volatility	-0.0317	-0.0362	-0.00309	0.0100	-0.0336	-0.0427	-0.0114	-0.0449
	(0.0520)	(0.0520)	(0.0595)	(0.0401)	(0.0504)	(0.0551)	(0.0583)	(0.0600)
Investment Policy Volatility	0.0511*	0.0498*	0.0404*	0.0393***	0.0476*	0.0465	0.0450*	0.0606
	(0.0250)	(0.0279)	(0.0233)	(0.0151)	(0.0259)	(0.0367)	(0.0265)	(0.0463)
Inflation Volatility	0.743*	0.574**	0.627	0.442*	0.695	0.556	0.700*	0.751**
	(0.389)	(0.266)	(0.408)	(0.237)	(0.415)	(0.382)	(0.362)	(0.351)
Initial GDP per capita	0.290	0.369	0.307	0.678	0.268	0.265	1.432	-0.0929
	(0.987)	(0.937)	(0.548)	(0.681)	(0.554)	(0.701)	(1.551)	(1.010)
Government Size	-0.154***	-0.0821	-0.0403	0.00460	-0.139*	-0.161***	-0.0652	-0.145
	(0.0468)	(0.0762)	(0.100)	(0.100)	(0.0707)	(0.0558)	(0.0949)	(0.152)
Investment Share	0.0446	0.0425	0.0135	0.0379	0.0570	0.0454	0.0247	0.0138
	(0.0437)	(0.0372)	(0.0255)	(0.0314)	(0.0631)	(0.0482)	(0.0449)	(0.0440)
Trade/GDP		0.00382						
		(0.00689)						
Loan/GDP			-0.00241					
			(0.00575)					
Saving/GDP				0.000454				
				(0.00601)				
GDP Size					0.351			
					(0.834)			
Education						-0.200		
						(0.454)		
SOE TIFA Share							-0.00836	
							(0.0223)	
Stable Population Share								0.00538
								(0.0745)
Constant	0.703	-0.598	0.296	-3.248	-2.022	2.698	-8.818	3.878
	(6.882)	(7.373)	(4.552)	(5.668)	(7.302)	(5.111)	(13.25)	(10.93)
Observations	174	172	174	170	174	174	174	174
Number of Provinces	29	29	29	29	29	29	29	29
Arellano-Bond AR(1) Test	0.0122	0.0540	0.0396	0.0588	0.0167	0.0190	0.0551	0.0146
Arellano-Bond AR(2) Test	0.740	0.486	0.363	0.213	0.838	0.527	0.967	0.685
Sargan Over-ID Test	0.987	0.941	0.998	0.996	0.999	0.969	0.993	0.962
Hansen Over-ID Test	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Note: Dependent variable is growth volatility measured as the standard deviation of GDP growth over a period. Period dummies are controlled in regression. Robust standard errors are in parentheses. ***, ** and * represent $p<0.01$, $p<0.05$ and $p<0.1$, respectively.

Table 7: Robustness Tests of Panel GMM Estimation Results with Initial Conditions of Controls

VARIABLES	(1) OLS	(2) WT	(3) Quantile	(4) FE	(5) D-GMM	(6) S-GMM1	(7) S-GMM2	(8) D-GMM	(9) S-GMM1	(10) S-GMM2
Fiscal Policy Volatility	-0.0210	-0.0233	-0.0224	0.0135	-0.109	-0.0797**	-0.0814	-0.00822	-0.0564**	-0.0496
	(0.0230)	(0.0202)	(0.0140)	(0.0293)	(0.0844)	(0.0387)	(0.0569)	(0.0325)	(0.0251)	(0.0499)
Investment Policy Volatility	0.0518***	0.0492***	0.0524***	0.0488**	0.0735*	0.0724***	0.0564**	0.0541**	0.0620***	0.0363
	(0.0125)	(0.0111)	(0.00948)	(0.0183)	(0.0369)	(0.0248)	(0.0214)	(0.0239)	(0.0210)	(0.0314)
Inflation Volatility	0.372***	0.344***	0.279***	0.266*	0.775***	0.581***	0.703**	0.425**	0.453**	0.660*
	(0.140)	(0.124)	(0.0802)	(0.147)	(0.267)	(0.209)	(0.270)	(0.206)	(0.177)	(0.344)
Initial GDP per capita	-0.0545	-0.0427	0.0609	0.757	2.961	0.118	0.148	-0.591	-0.0659	0.365
	(0.174)	(0.162)	(0.187)	(0.704)	(2.959)	(0.279)	(0.332)	(1.106)	(0.232)	(0.410)
Initial Government Size	-0.102***	-0.0980***	-0.0551*	-0.00456	-0.0207	-0.0777**	-0.0632	-0.0346	-0.115***	-0.111
	(0.0365)	(0.0335)	(0.0289)	(0.0439)	(0.0728)	(0.0341)	(0.0462)	(0.0436)	(0.0351)	(0.0799)
Initial Investment Share	0.0316*	0.0286**	0.00513	0.0312	0.00856	0.0241	0.00871	0.0496*	0.0358**	-0.00793
	(0.0172)	(0.0140)	(0.0112)	(0.0188)	(0.0315)	(0.0165)	(0.0195)	(0.0261)	(0.0171)	(0.0289)
Constant	3.495**	3.534**	2.976**	-3.279		2.287	2.369		3.677**	1.903
	(1.645)	(1.423)	(1.451)	(5.358)		(1.936)	(2.736)		(1.676)	(2.853)
Observations	174	174	174	174	145	174	174	145	174	174
R-squared	0.638	0.656		0.671						
Number of Provinces				29	29	29	29	29	29	29
Arellano-Bond AR(1) Test					0.00992	0.0137	0.0135	0.0298	0.0174	0.0118
Arellano-Bond AR(2) Test					0.508	0.934	0.950	0.286	0.546	0.446
Sargan Over-ID Test					0.917	0.796	0.796	0.860	0.706	0.706
Hansen Over-ID Test					0.414	0.998	0.998	1.000	1.000	1.000

Note: Dependent variable is growth volatility measured as the standard deviation of GDP growth over a period. Period dummies are controlled in regression. Robust standard errors are in parentheses. ***, ** and * represent p<0.01, p<0.05 and p<0.1, respectively.

Table 8: Robustness Tests of Panel GMM Estimation Results with Alternative Estimation Specification of Discretionary Policy

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
VARIABLES	OLS	WT	Quantile	FE	D-GMM	S-GMM1	S-GMM2	D-GMM	S-GMM1	S-GMM2
Fiscal Policy Volatility	-0.0152	-0.0176	-0.0140	0.00807	-0.0100	-0.0383	-0.0749	-0.0322	-0.0455*	-0.0672
	(0.0239)	(0.0209)	(0.0153)	(0.0332)	(0.0462)	(0.0282)	(0.0520)	(0.0361)	(0.0233)	(0.0439)
Investment Policy Volatility	0.0430***	0.0407***	0.0423***	0.0494***	0.0408*	0.0433**	0.0422**	0.0472**	0.0468***	0.0487*
	(0.00961)	(0.00887)	(0.00777)	(0.0144)	(0.0215)	(0.0175)	(0.0204)	(0.0205)	(0.0160)	(0.0254)
Inflation Volatility	0.386***	0.356***	0.274***	0.231	0.581***	0.438**	0.527	0.489**	0.581***	0.692***
	(0.138)	(0.126)	(0.0757)	(0.142)	(0.202)	(0.166)	(0.348)	(0.237)	(0.186)	(0.223)
Initial GDP per capita	-0.138	-0.0764	0.113	0.837	2.702	-0.0769	-0.522	-0.210	-0.00171	0.277
	(0.180)	(0.165)	(0.177)	(0.721)	(1.851)	(0.249)	(0.493)	(1.927)	(0.242)	(0.695)
Government Size	-0.0987**	-0.0885**	-0.0490*	0.0189	-0.0395	-0.103**	-0.145	-0.00823	-0.110***	-0.0630
	(0.0383)	(0.0353)	(0.0284)	(0.0507)	(0.0671)	(0.0430)	(0.0990)	(0.0581)	(0.0378)	(0.104)
Investment Share	0.0407**	0.0333**	0.00449	0.0548**	0.0534*	0.0434**	-0.00950	0.0520	0.0353*	-0.000814
	(0.0201)	(0.0168)	(0.0122)	(0.0253)	(0.0303)	(0.0202)	(0.0409)	(0.0332)	(0.0192)	(0.0195)
Constant	3.892**	3.651***	2.588*	-4.662		3.613**	8.763*		3.085*	1.509
	(1.514)	(1.371)	(1.317)	(5.632)		(1.758)	(4.978)		(1.672)	(5.907)
Observations	174	174	174	174	145	174	174	145	174	174
R-squared	0.642	0.655		0.683						
Number of Provinces				29	29	29	29	29	29	29
Arellano-Bond AR(1) Test					0.0146	0.0151	0.0204	0.00864	0.00922	0.0182
Arellano-Bond AR(2) Test					0.895	0.474	0.686	0.738	0.786	0.956
Sargan Over-ID Test					0.971	0.862	0.862	0.963	0.973	0.973
Hansen Over-ID Test					1.000	1.000	1.000	0.999	1.000	1.000

Note: Dependent variable is growth volatility measured as the standard deviation of GDP growth over a period. Period dummies are controlled in regression. Robust standard errors are in parentheses. ***, ** and * represent p<0.01, p<0.05 and p<0.1, respectively.

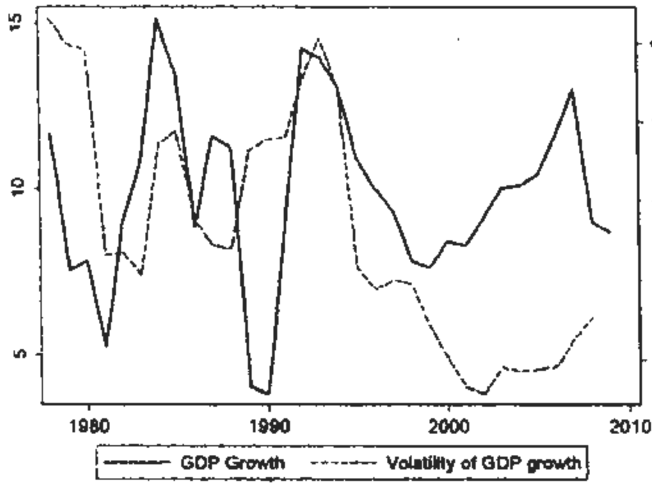

Figure 1: GDP Growth and Rolling Volatility
Note: Sample period covers 1978 to 2008. GDP growth and Volatility of GDP Growth correspond to left scale and right scale, respectively. A rolling window of 5 years is used.

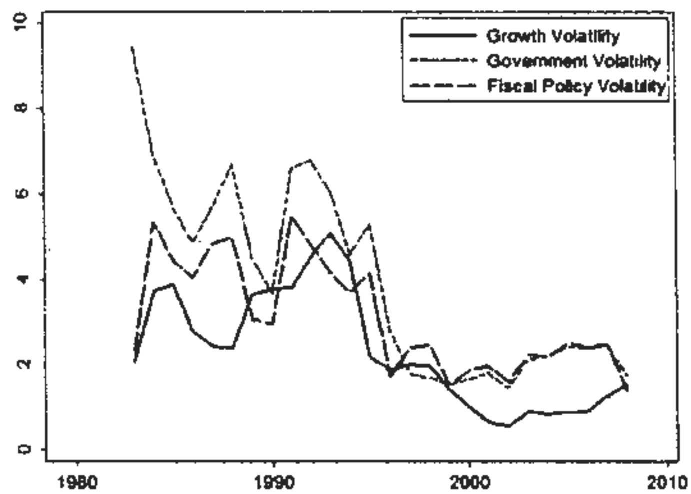

Figure 2: Rolling Growth Volatility and Fiscal Policy Volatility
Note: Sample period covers 1978 to 2008. A rolling window of 5 years is used.

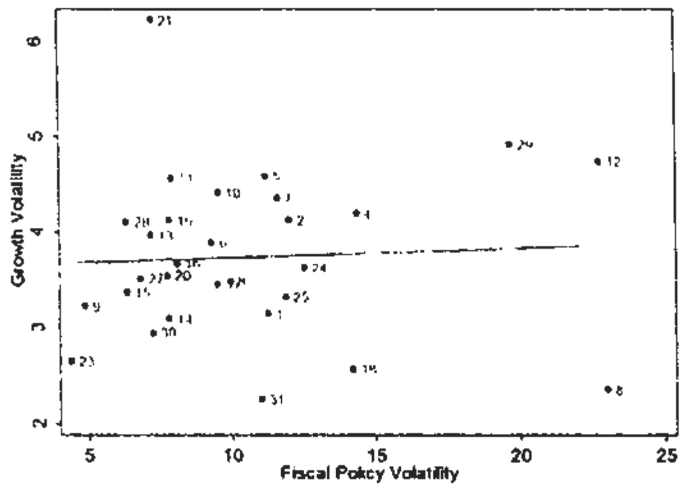

Figure 3: Growth Volatility and Fiscal Policy Volatility
Note: Sample period covers 1978 to 2008. Numbers in the figure refer to the codes of Chinese provinces: Beijing (1), Tianjin (2), Hebei (3), Shanxi (4), Inner Mongolia (5), Liaoning (6), Jilin (7), Heilongjiang (8), Shanghai (9), Jiangsu (10), Zhejiang (11), Anhui (12), Fujian (13), Jiangxi (14), Shandong (15), Henan (16), Hubei (17), and Hunan (18), Guangdong (19), Guangxi (20), Hainan (21), Chongqing (22), Sichuan (23), Guizhou (24), Yunnan (25), Tibet (26), Shaanxi (27), Gansu (28), Qinghai (29), Ningxia (30), and Xinjiang (31). In this study, Chongqing and Tibet are excluded from the sample.

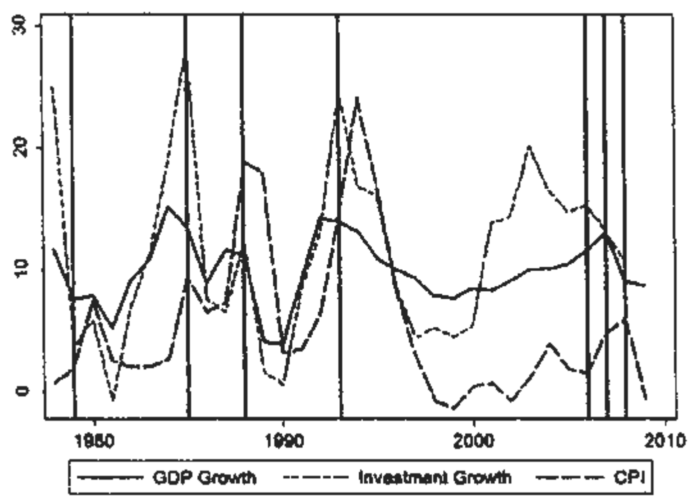

Figure 4: Business Cycles and Macro-Control
Note: Sample period covers 1978 to 2008. The vertical solid lines indicate the timing of imposing macro-control policies.

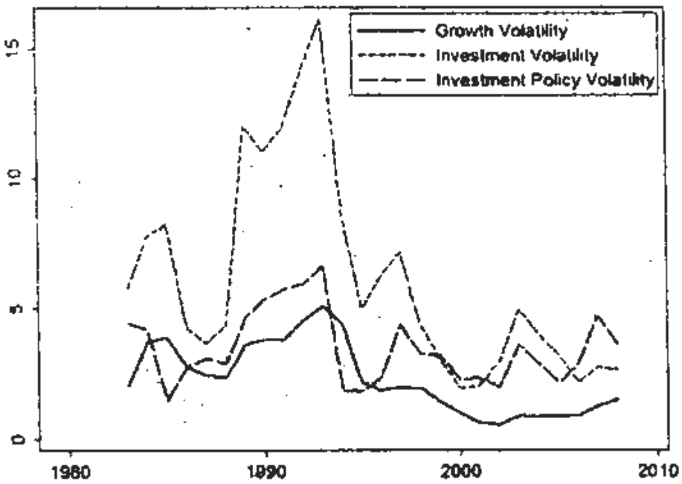

Figure 5: Rolling Growth Volatility and Investment Policy Volatility
Note: Sample period covers 1978 to 2008. A rolling window of 5 years is used.

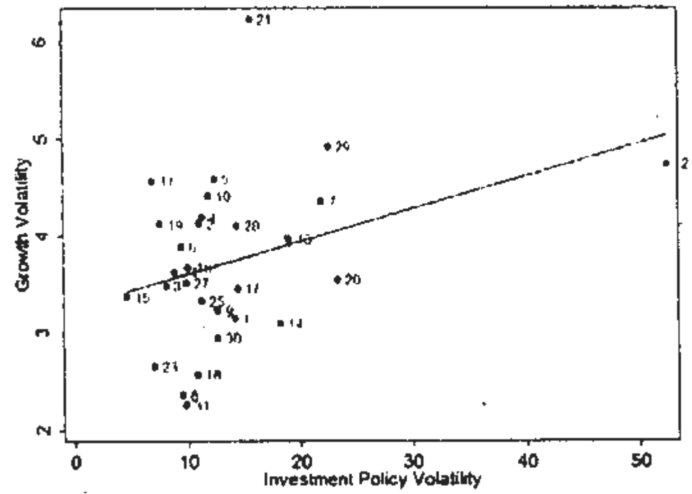

Figure 6: Growth Volatility and Investment Policy Volatility
Note: Sample period covers 1978 to 2008. Numbers in the figure refer to the codes of Chinese provinces: Beijing (1), Tianjin (2), Hebei (3), Shanxi (4), Inner Mongolia (5), Liaoning (6), Jilin (7), Heilongjiang (8), Shanghai (9), Jiangsu (10), Zhejiang (11), Anhui (12), Fujian (13), Jiangxi (14), Shandong (15), Henan (16), Hubei (17), and Hunan (18), Guangdong (19), Guangxi (20), Hainan (21), Chongqing (22), Sichuan (23), Guizhou (24), Yunnan (25), Tibet (26), Shaanxi (27), Gansu (28), Qinghai (29), Ningxia (30), and Xinjiang (31). In this study, Chongqing and Tibet are excluded from the sample.

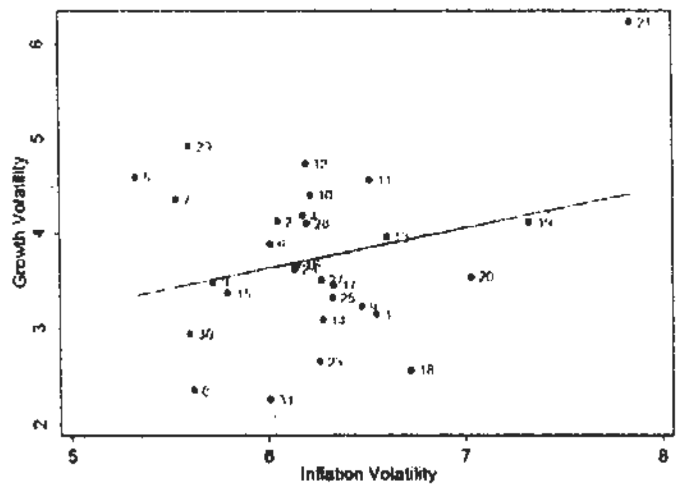

Figure 7: Growth Volatility and Inflation Volatility

Note: Sample period covers 1978 to 2008. Numbers in the figure refer to the codes of Chinese provinces: Beijing (1), Tianjin (2), Hebei (3), Shanxi (4), Inner Mongolia (5), Liaoning (6), Jilin (7), Heilongjiang (8), Shanghai (9), Jiangsu (10), Zhejiang (11), Anhui (12), Fujian (13), Jiangxi (14), Shandong (15), Henan (16), Hubei (17), and Hunan (18), Guangdong (19), Guangxi (20), Hainan (21), Chongqing (22), Sichuan (23), Guizhou (24), Yunnan (25), Tibet (26), Shaanxi (27), Gansu (28), Qinghai (29), Ningxia (30), and Xinjiang (31). In this study, Chongqing and Tibet are excluded from the sample.

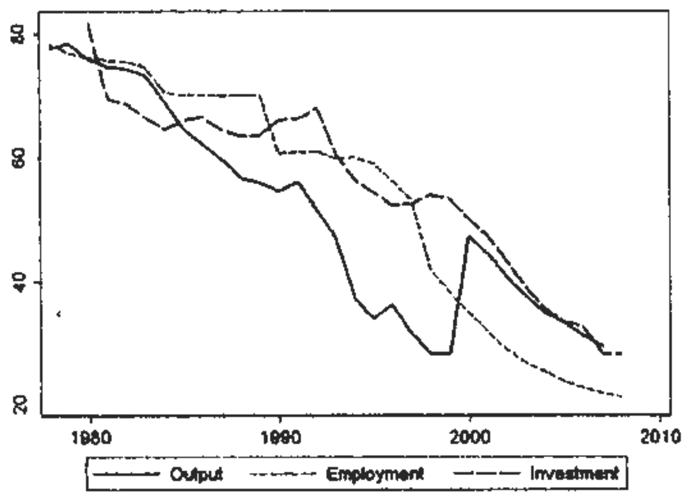

Figure 8: SOEs Shares in Aggregate Economy

Note: Sample period covers 1978 to 2008. Output, Employment and Investment represent the SOEs' shares in industrial output, urban employment, and investment in fixed assets, respectively.

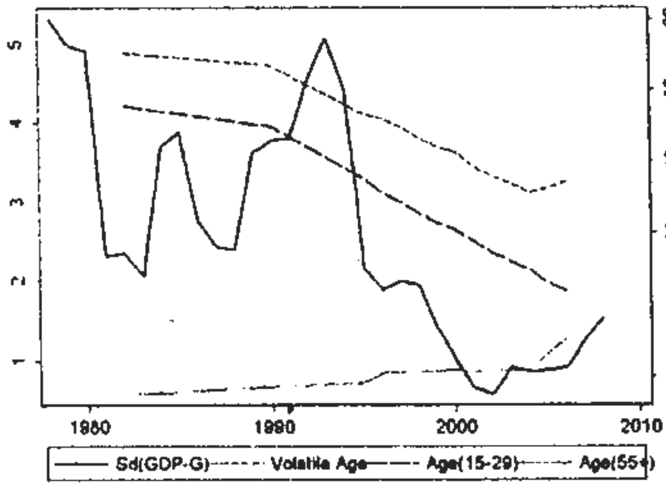

Figure 9: Rolling Volatility of Economic Growth and Changes of Age Structure of Labor Forces
Note: Sample period covers 1978 to 2008. Sd(GDP-G) represents the rolling standard deviation of GDP growth with a window of 5 years, and corresponds to left scale. Volatile Age, Age(15-29) and Age(55+) represent the employment shares of volatile age (age 15-29 and 55 above), age 15-29, and age 55 above, respectively. Volatile Age, Age(15-29) and Age(55+) correspond to right scale.

On the Link between Growth and Volatility: Evidence from China

Abstract

Unlike the conventional wisdom that growth and volatility correlate negatively across countries, this essay finds a significant and positive growth-volatility link across Chinese provinces in the reform period. This positive link remains significant using both cross-sectional and panel samples, and using both OLS and GMM estimates. The results are robust to considering the effects of some potential misspecifications, additional control variables, alternative volatility measures, and alternative period division methods. More discussions at the disaggregate level are further conducted. From the demand side, the aggregate volatility is negatively correlated with rural consumption growth, but positively and significantly correlated with urban consumption growth. At the sectoral level, more volatile sectors command higher investment rate and higher value-added growth. This essay also finds that the expected volatility has positive effect on growth, while both fiscal and investment policy volatilities are significantly harmful to growth. However, the significances of policy volatilities vanish once expected volatility is included in the analysis. It partly confirms the analytical argument that the growth-volatility link in China is mainly driven by the positive volatility component. Moreover, a stable policy environment is vital to the economic growth of China despite a positive aggregate growth-volatility link.

JEL: E32; O40; O53; R11

Keywords: Growth; Volatility; Business Cycles; Chinese Economy

1 Introduction

The relationship between growth and volatility has received increasing research attention in recent years. In theory, the growth-volatility link can arise from either the joint determination of volatility and growth as endogenous variables, or a causal effect from one variable to the other. The growth-volatility link may be either positive or negative depending on the mechanisms driving the relationship. For example, when both variables are jointly determined, this link could be positive with the consideration of precautionary saving, risk-return nexus, creative destruction during recessions, etc. The growth-volatility link could also be negative if recessions hamper or destroy human capital developing by decreasing learning-by-doing. In the case of causal effect from one to the other, the growth-volatility link could be negative if the volatility reflects political uncertainty and weak institutional environment.

To study the empirical growth-volatility link is an important research topic since it may suggest that policies and exogenous shocks that affect volatility can also influence economic growth. Even if volatility is considered a second-order issue, its link with growth indicates that volatility could have indirect first-order welfare implications.

On the one hand, even if growth and volatility are determined endogenously, the discussion of growth-volatility link is valuable for verifying the inferences of some specific theories. For instance, if the growth-volatility link is estimated to be positive, is suggests that theories leading to a negative link cannot be the whole picture of the real economy, and some other factors, i.e. precautionary saving or creative destruction, may account for significant part of the growth mechanism, vice versa.

On the other hand, in situations where volatility arising from the exogenous factors, i.e. institutional weakness, volatility may have a causal effect (mostly negative) on growth if the relationship is estimated properly, and the study on this link offers policy implications for the importance of improving institutional and policy environment and implementing macro policies to tame volatility.

The seminal empirical work of Ramey and Ramey (1995) concludes that growth and volatility are negatively correlated. This conclusion is regarded as a conventional wisdom in cross-country studies and is later confirmed by Martin and Rogers (2000), and Kose, Prasad, and Terrones (2006). However, recent studies also find that trade and financial integration have weakened this negative relationship during the 1990s (Kose, Prasad and Terrones, 2006), and that the growth-volatility link is debatable for developing countries (Martin and Rogers, 2000; Turnovsky and Chattopadhyay, 2003). Moreover, some argue that the significant negative growth-volatility link in cross-country studies may be caused by measurement error and low data quality (Dawson et al., 2001). They further employ regional data within a country to examine the link, e.g. for US states and Canadian provinces, and fail to find a significant negative link (Dawson and Stephenson, 1997; Dejuan and Gurr, 2004).

This essay empirically studies the relationship between growth and volatility for China using its provincial panel data over the last three decades (1978–2008). The Chinese case is of great interest for several reasons.

First, as the largest developing country in the world, China exhibits an interesting stylized fact that high economic growth is accompanied by cyclical growth pattern. Over the last three decades, China has achieved impressive economic performance, with mean growth of GDP per capita reaching 8.7%. Meanwhile, the cyclical growth pattern of the Chinese economy is pronounced.[53] This fact can also be observed in some other developing countries.[54] Investigating the Chinese case can add some new evidence to the existing discussion of growth-volatility link for developing countries (Turnovsky and Chattopadhyay, 2003; Loayza et al., 2007).

Second, Chinese provinces show noticeable variances in both economic growth and volatility. Over the last three decades, the highest and lowest mean growth rates of provincial GDP per capita are 7.3% (Ningxia) and 11.5% (Zhejiang), whereas the highest and lowest standard deviation of economic growth are 2.3% (Xinjiang) and 6.5% (Hainan), respectively. We also find a significant and positive unconditional relationship between growth and volatility for Chinese provinces.[55] This observation is remarkably different from the negative link found in cross-country studies.

Lastly, as Hess and Shin (1997; 1998) argue, the sample of regional economies within a country can provide a natural experiment for understanding international economic issues. Moreover, using the cross-provincial data within a country to a large extent can avoid the international compatibility problems of data (Barro, 1991; Li and Zhang, 2007).

The main findings of this study are summarized as follows. A significant and positive link between growth and volatility is evident among Chinese provinces both in cross-sectional and panel samples, and it is robust to both OLS and GMM estimates. Further robustness tests confirm this positive link after taking

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[53] If we define a business cycle as a period from a trough to a peak of economic growth or vice versa, China has experienced five simple cycles since 1978. The output volatility, measured as the standard deviation of per capita GDP growth, is 2.8%, with 2.3% and 13.7% as the lowest and highest growth rates, respectively.

[54] For instance, the mean and standard deviation of GDP per capita growth of India over the last three decades are 4.4% and 2.4%, respectively.

[55] In the reform period (1978–2008), the unconditional relationship between average rate of GDP per capita growth and its standard deviation for 30 Chinese provinces (Tibet is excluded) is 0.587, and it is significant at the 1% significance level.

into account the effects of several potential misspecifications (including provincial size, sample outliers, province fixed-effect, and endogeneity issue) and additional control variables. The benchmark results are also robust to alternative volatility measures and alternative period division methods.

We further discuss the growth-volatility link from several disaggregate perspectives. Interestingly, volatility is negatively associated with the growth of rural household consumption, but positively and significantly associated with that of urban household consumption. Moreover, similar to the cross-country results in Imbs (2007), we also uncover a significant and positive growth-volatility link at the sectoral level across Chinese provinces, and it shows that a more volatile sector commands higher investment rates and higher value-added growth. Lastly, we find that rather than the aggregate investment, the non-state-owned enterprise (non-SOE) investment and foreign direct investment (FDI) are the important channels through which volatility positively correlates with economic growth.

A simple analytical framework is proposed to explain the distinct growth-volatility link in China. The aggregate volatility is considered to consist of a positive and a negative component. The negative volatility component of China, which mainly stems from the roughly identical basic institutional factors across Chinese provinces, is much less important than the positive volatility component in the variance of aggregate volatility. Therefore, the aggregate growth-volatility link mainly reflects the role of positive volatility component, maybe through the channels of non-SOE investment and FDI. In addition, we illustrate that the expected volatility, which reflects part of positive volatility component, has positive effect on growth, while both the fiscal and investment policy volatilities significantly hamper economic growth.

Once both expected volatility and policy volatility are considered, the former remains significant and positive, whereas the latter loses its significance. It provides some support to the analytical conclusion that the positive volatility component dominates the growth-volatility link. Moreover, it also suggests that a better institutional environment, stemming from stable and predictable policies of far-sighted local governments and benign interactions between the government and market, is crucial to the long-term economic growth of China.

Our study extends the existing literature on the Chinese economy and empirical growth-volatility link in several dimensions. First, to our best knowledge, this study is the first attempt to investigate the relationship between growth and volatility in China at both the aggregate and disaggregate levels. This essay can provide additional evidence to the empirical discussion on growth-volatility link in the context of the developing countries. Second, we examine whether some theoretical considerations can explain the positive growth-volatility link in China. We also propose an analytical framework to explain the difference in growth-volatility link between cross-country and Chinese provincial samples. Lastly, our discussions provide several interesting results, which may deserve more attention in future studies on Chinese business cycles. For instance, there is a pronounced difference between the link of output volatility with the consumption growth of rural residents and that with the consumption growth of urban residents.

The remainder of this essay is organized as follows. Section 2 gives a literature survey of studies on the relationship between growth and volatility, and Chinese business cycle. Section 3 provides the data description and several stylized facts on the link between growth and volatility. Section 4 reports the empirical results. Robustness tests are conducted in Section 5. More discussions at the disaggregate level are made in Section 6. Lastly, Section 7 provides the conclusion.

2 Literature Review

The relationship between growth and volatility has been attracted intense attention in recent years. Traditionally, volatility and growth are separately treated in different fields of economic research. Studies on business cycles take for granted that the distinction between growth trend and business cycles is an artificial one, and both growth and volatility are determined by the same set of shocks. On the other hand, long-term growth theories assume that short-term shocks have no impact on long-term growth and focus on the existence and stability of a long-term deterministic growth path.

Several studies argue that the benefits of understanding fluctuations are trivial compared with those of understanding growth, and the welfare costs of the volatility of aggregate consumption and output are negligible (Lucas, 1987; Otrok, 2001; Lucas, 2003).[56] However, several researchers have changed the assumptions of Lucas on preferences and find that the welfare gain from consumption volatility reduction is potentially fairly large, especially for developing countries (Pallage and Robe, 2003; Barlevy, 2004).[57] Chen and Zhou (2006) find that the welfare cost of the business cycle of China is 22 times larger than that of the U.S.

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[56] Otrok (2001) develops a model that allows for potential time-non-separabilities in preference, and finds that the welfare cost of business cycles is on the same order as that in the study by Lucas (1987). Lucas (2003) argues that the potential benefits from stabilization policies are on the order of hundredths of a percent of consumption, maybe two orders of magnitude smaller than the potential gains of fiscal reforms.

[57] Barlevy (2004) argues that volatility can reduce growth starting from a given initial consumption, and it can imply substantial welfare effects. He also shows empirical evidence that the welfare cost in the United States is substantial, that is, two orders of magnitude greater than the estimation by Lucas (1987). Pallage and Robe (2003) find that the magnitude of macroeconomic fluctuations is much severer in developing countries, and the welfare cost of consumption volatility is far from trivial. Even in several poor countries, the welfare gains from reducing volatility may exceed those from an additional percentage of economic growth (Pallage and Robe, 2003).

Theoretically, the relationship between economic growth and volatility is ambiguous. Both positive and negative links can be inferred in terms of different model settings and growth mechanisms.

One theoretical strand focuses on the responses of the investors to the uncertainty about the future, policy, and so on. The effect of uncertainty on investment and growth can be either positive or negative. With the presence of irreversibility investment (Bernanke, 1983; Pindyck, 1991; Aizenman and Marion, 1993), or imperfect competition and decreasing return to scale in production (Caballero, 1991), higher volatility, which means higher uncertainty, can lead to lower investment and lower economic growth. However, when an economy is facing a choice between technologies with high variance and high expected returns and those with low variance and low expected returns, the link between growth and volatility may be positive (Black, 1987; 2009). Moreover, with the concern of precautionary saving (Mirman, 1971), or perfect competition and constant return to scale in production (Caballero, 1991), the relationship between uncertainty and investment (hence growth) may be positive.

Another strand considers the structural interaction between growth and business cycle fluctuations as the major explanation. Recessions may reduce the opportunity cost of productivity improvement (Aghion and Howitt, 1992; Caballero and Hammour, 1996). The sign of the relationship between growth and volatility depends on whether the activity generating productivity growth is a complement or a substitute to production (Aghion and Saint-Paul, 1998a; b). Aghion and Saint-Paul (1998a; b) show that in the case of complementarities and the case of substitutions, the business cycle volatility has both negative and positive effects on long-term productivity growth.

Moreover, some studies attribute the link between growth and volatility to the role of trade and financial liberalization. The deepening globalization and financial liberalization make an economy more vulnerable to external shocks, and lead to financial fragility and greater incidence of crises. At the same time, they also bring about high economic growth. Therefore, the countries with higher economic growth are typically those that have experienced significant business cycles (Tornell, Westermann and Martinez, 2004). A positive link between economic growth and negative skewness of credit growth across countries can be inferred (Ranciere, Tornell and Westermann, 2003), suggesting a positive relationship between systemic risk and economic growth since the financial liberalization leads to higher growth but also greater incidence of crises (Ranciere, Tornell and Westermann, 2008).

A large number of empirical studies have contributed to the issue of the relationship between growth and volatility. Most of them, for example, Ramey and Ramey (1995), Martin and Rogers (2000), Kose, Prasad and Terrones (2006), among others, focus on the link at the aggregate level using cross-country datasets.. Recent studies employ industry data or firm data to investigate the relationship between volatility and growth at the disaggregate level (Imbs, 2002; 2007; Chong and Gradstein, 2009).

Most cross-country empirical studies regress long-term economic growth on the volatility measure and a set of standard control variables suggested by Levine and Renelt (1992). They find that there is a significant and negative relationship between long-term growth and volatility, no matter the volatility is measured as an economic growth fluctuation (Ramey and Ramey, 1995; Martin and Rogers, 2000; Kose, Prasad and Terrones, 2006; Burnside and Tabova, 2009), or policy uncertainty (Aizenman and Marion, 1993; Fatás and

Mihov, 2005). The influential work of Ramey and Ramey (1995) finds that counties with higher volatility have lower growth, and the negative relationship is strengthened after controlling standard control variables using both sample of 92 countries and a sub-sample of OECD countries. This negative link has been confirmed by Martin and Rogers (2000) using a sample of industrial countries and European regions. Kose, Prasad, and Terrones (2006) employ a more comprehensive dataset covering 85 countries over the period 1960–2000,[58] and Fatás and Mihov (2005) using policy uncertainty as volatility measure.

Moreover, Dawson et al. (2001) argue that the significant negative growth-volatility relationship in Ramey and Ramey (1995) may have been caused by measurement error in cross-country data. They include data quality dummy variables in the estimation and then fail to find a significant growth-volatility link. To avoid data quality problem, Dawson et al. (1997) and Dejuan and Gurr (2004) employ data from US states and Canadian provinces to examine the growth-volatility link. They find there is no significant link and a weak positive link for US states and Canadian provinces, respectively.

However, there is no consensus on the channel through which volatility affects growth. Ramey and Ramey (1995) argue that the negative growth-volatility link mainly comes from the effect of innovation volatility and uncertainty on growth rather than the investment channel.[59] Martin and Rogers (2000) suggest that the negative relationship can come neither from uncertainty nor from the investment instability, but from a labor channel. In contrast, Aizenman and Marion (1999) find a significant negative relationship between

[58] Kose, Prasad and Terrones (2006) investigate the link in the context of globalization, and further find that globalization (trade and financial integration) weakens this negative relationship.

[59] Ramey and Ramey (1995) also find a negative impact of government spending volatility on growth, which is a complementary result to Alesina et al. (1996), who argue that more political instability leads to lower economic growth.

volatility and private investment. Moreover, the negative link is exacerbated in countries with underdeveloped institutions or less advanced financial development (Hnatkovska and Loayza, 2005; Aghion et al., 2010).

When using data at the disaggregate level, several studies find interesting results, which are different from those revealed in the aggregate investigations. Although the link between growth and volatility at the aggregate level remains significant negative, Imbs (2007) unfolds a significant positive relationship at the sectoral level.[60] He argues that the negative relationship at the aggregate level only reflects that the country-specific component of aggregate variance is detrimental to aggregate growth. Whereas the analysis at the sectoral level isolates the component specific to each sector from aggregate volatility, and shows that the volatile activities within countries grow fast and command high investment rates. However, using a cross-country, firm-level dataset, Chong and Gradstein (2009) reveal a significant and negative relationship between volatility and firm growth.[61]

Despite the fruitful studies on the relationship between growth and volatility using the cross-country samples and the samples from the developed countries, the link for the developing countries are less investigated and even controversial in existing literature. For example, Martin and Rogers (2000) find that the significant negative link found in developed countries does not hold in developing countries. However, Turnovsky and Chattopadhyay (2003) show that in developing countries, facing an imperfect world capital market, volatilities of terms of trade, government expenditure, and monetary policy have significant and negative effects on the equilibrium growth rate.

[60] The dataset covers manufacturing activities at the three-digit level in 47 countries.

[61] Chong and Gradstein (2009) use a dataset covering more than 5,600 firms across over 80 countries. They further find that weak institutions magnify the negative growth effect of volatility.

Furthermore, Kose, Prasad, and Terrones (2006) find a negative relationship among developing countries, and that globalization and financial integration weaken the negative link.[62]

To better understand the relationship between growth and volatility in the context of developing countries, we use provincial level data of China to investigate this debatable issue. Using cross-regional data within a country can make the problems of data comparability less severe (Barro, 1991; Levine and Zervos, 1996; Dawson et al., 2001; Li and Zhang, 2007). More importantly, as the largest developing country, China has experienced both outstanding economic growth and significant cyclical growth pattern over the past three decades, and the cyclical "stop-go" pattern of economic growth is considered the major feature of Chinese business cycle (Yusuf, 1994; Naughton, 1995a; b; Yu, 1997).

The studies on the growth volatility and business cycles of the Chinese economy mainly focus on the characteristics of the business cycles of China (Ho and Tsui, 2004; Laurenceson and Rodgers, 2010), co-movement of output and inflation (Oppers, 1997; Gong and Lin, 2008), and economic synchronization within China (Xu, 2002; Xu and Voon, 2003). However, to the knowledge of the author, they have not discussed the growth-volatility link. Given the noticeable features of Chinese business cycles, some studies devote their efforts to discuss the underlying explanations for the cyclical pattern of the Chinese economy. Several complementary explanations are considered. The first one focuses on the commitment of the Chinese government to SOEs and decentralization, and argues that due to the imperfect control of credit

[62] Using a panel dataset, Kose, Prasad, and Terrones (2006) show that a more open and more financially developed country can tolerate higher volatility without detrimental effects on long-term economic growth. They also find that there is a significant positive link between growth and volatility among industrial countries rather than a significant negative one in Ramey and Ramey (1995).

allocation by the Chinese government, the shift from flexible credit plan to administrative credit plan and vice versa result in a cyclical pattern of the economic growth of China (Brandt and Zhu, 2000; 2001). The second one associates the cyclical growth pattern with the implementations of macro-control policies (Yu, 1997; Michael, 2004). The third one employs different accounting methods to gauge the dominant factors of Chinese business cycle, such as Gao (2007), He, Chong and Shi (2009), and Hsu and Zhao (2009).

Although both the positive and negative links between growth and volatility can be inferred from theoretical analyses, the finding that volatility is negatively associated with growth among countries, especially industrial economies, is still considered a conventional wisdom. However, as far as developing countries are concerned, the empirical studies have controversial conclusions on this link. Using the provincial data of China to investigate the volatility-growth link, this study can contribute to the literature in two ways. One is by providing empirical evidence of this debatable link in the context of the largest developing country. The other is by filling the research gap in the literature on Chinese business cycles.

3 Data and Stylized Facts

We examine the relationship between growth and volatility using a provincial panel dataset that covers 30 provinces[63] over the past three decades (1978–2008). This dataset is mainly collected from the recently published *China Compendium of Statistics 1949–2009* and various issues of *Chinese Statistical Yearbook*. In addition, several supplementary data sources are employed, including the *Data of Gross Domestic Product of China 1952–1995*, the *Data*

[63] Tibet is excluded in the dataset because it is very different from other provinces, and the quality of data on it is low.

of *Gross Domestic Product of China 1996–2002*, and the *Data of Gross Domestic Product of China 1952–2004*. The fact that the national account data for the period 1993–2004 on China and all provinces differ in various statistical publications is noteworthy since the 2004 Economic Census remarkably re-estimates the national account data for this period.[64] The data in recently released publication are used and carefully cross-checked among different sources.

Following the empirical studies on economic growth and the relationship between growth and volatility (Levine and Renelt, 1992; Ramey and Ramey, 1995; Martin and Rogers, 2000; Kose, Prasad and Terrones, 2006), we examine the case of China using its provincial data. Both the cross-sectional and panel data samples of China are constructed in this study. The cross-sectional sample considers the past three decades (1978–2008) as a whole. Therefore, the long-term economic growth and volatility are the mean value and the standard deviation of real per capita GDP growth over the period 1978–2008. Other variables employed in this essay are also calculated over the whole period. The provincial panel sample divides the whole period into six five-year consecutive non-overlapping sub-periods.[65] Hence, the average economic growth, volatility, and other variables are all estimated over each of the six sub-periods. Therefore, we have a provincial panel sample for 30 provinces over six consecutive sub-periods.

The basic growth regression with volatility is specified as follows:

[64] The main data source is the *China Compendium of Statistics 1949–2009*. The national account data for 1993–2004 of all provinces are based on the *Data of Gross Domestic Product of China 1952–2004* and *Data of Gross Domestic Product of China 1996–2002*. The data for 1978–1992 are from the *Data of Gross Domestic Product of China 1952–1995*, and those after 2004 are from the *China Compendium of Statistics 1949–2009* and various issues of *Chinese Statistical Yearbook*.

[65] The year 2008 is included in the last sub-period.

$$g_{i,T} = \alpha + \beta\sigma_{i,T} + \gamma y_{i,T} + \delta X_{i,T} + \varepsilon_{i,T} , \quad (1)$$

where $g_{i,T}$, $\sigma_{i,T}$, $y_{i,T}$, and $X_{i,T}$ are the average real per capita GDP growth, volatility of real per capita GDP growth, initial value of real per capita GDP, and other control variables for the period T, respectively. Here, GDP is converted to be at constant 2000 price, and the economic growth is estimated as the log difference of real per capita GDP.

A standard set of control variables in a growth regression is suggested by Levine and Renelt (1992) and other authors of related studies. We should control the effects of the following variables: initial income level, initial human capital, investment share, population growth, and other potential explanatory factors.[66]

Human capital is measured as the average schooling years of population aged 6 and above. We only have population census data in 1982, 1990, and 2000, and population survey data in 1987, 1993, 1995–1999, and 2001–2008.[67] The schooling years for the person holding primary school, junior high school, senior high school, and college and above as their final degree are calculated as 6, 9, 12, and 16 years. The schooling years of illiterate population are 0. We then calculate the average schooling years using the shares of population with different education attainments as weights. Lastly, to fill the human capital

[66] Other variables may include government expenditure share, GDP share of agriculture sector, the size of an economy, and financial development, among others.

[67] The data sources for human capital estimation include the data of the *Third, Fourth, and Fifth China Population Census*, *China Statistical Yearbook* (1988–2008), *China Population Statistical Yearbook* (1988–2006), and *China Population and Employment Statistical Yearbook* (2007–2008).

data for the unavailable years, we get the human capital panel data for the years 1978–2008 through linear interpolation.[68]

We use the share of gross fixed capital formation (GFCF) in GDP as the proxy of investment share. Of course, an alternative measure of investment share is the ratio of the total fixed asset investment over GDP. The second measure can be employed to conduct robustness tests. The measure of population growth is the natural growth rate of population. Other variables, such as private sector, government size, and financial development, can be introduced in the corresponding sections.

Next, we discuss some stylized facts about the dynamics of the relationship between growth and volatility over time and across different regions in the reform period. In the beginning, Chinese provinces are divided into three groups: eastern, central, and western regions.[69] Table 1 reports the mean value of average growth and volatility for different regions over time.

[TABLE 1 HERE]

[FIGURE 1 HERE]

The first column of Table 1 describes the mean value of growth and volatility for all provinces and three regions over the whole period 1978–2008. The table shows that during the reform period, mean growth of the eastern region is the

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[68] We can get the human capital data for the years 1982–2008 through linear interpolation. We then apply the growth rate of average schooling years for the period 1982–1987 to the years 1978–1982, and finally we can obtain the human capital data for the whole reform period.

[69] Eastern region includes 11 provinces: Beijing (1), Tianjin (2), Hebei (3), Liaoning (4), Shanghai (9), Jiangsu (10), Zhejiang (11), Fujian (13), Shandong (15), Guangdong (19), and Hainan (21). Central region includes 8 provinces: Shanxi (4), Jilin (7), Heilongjiang (8), Anhui (12), Jiangxi (14), Henan (16), Hubei (17), and Hunan (18). Western region includes 12 provinces: Inner Mongolia (5), Guangxi (20), Chongqing (22), Sichuan (23), Guizhou (24), Yunnan (25), Tibet (26), Shaanxi (27), Gansu (28), Qinghai (29), Ningxia (30), and Xinjiang (31). The number in the parentheses is the index of the province. In this study, Tibet is excluded from the sample.

highest, followed by the central region and western region. The magnitudes of volatility are in the same order as those of mean growth, very roughly implying an unconditional positive link between economic growth and volatility. This unconditional positive link is also illustrated in Figure 1, which simply shows that cross-provincial link between economic growth and volatility turns out to be positive rather than negative for developing countries, according to Ramey and Ramey (1995), and Kose, Prasad, and Terrones (2006).

From Table 1, we can also find that China has experienced a slightly higher but remarkably less volatile economic growth in the second half of the reform period. The volatilities over the first 15 years for all regions remain relatively stable and high (around 4%), whereas in the second half of reform period, almost all provinces have experienced a drastic drop in output volatility (less than 2%). Before 1992, a region with higher growth is likely to suffer higher volatility. However, this relationship seems less prominent after 1992 not only because of the narrowing growth gap among regions but also because of the noticeable decline in volatility in the previously more volatile regions.

[FIGURE 2 HERE]

Here, the unconditional cross-provincial relationship between growth and volatility is positive, whereas the time-variant, growth-volatility link seems to be negative.[70] We further plot the growth and volatility of the panel sample after controlling the effects of period dummies in Figure 2. We find that there is also a positive link in the provincial panel sample, suggesting that the period-specific factor plays an important role in the growth-volatility link.

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[70] When we pool the panel data together, there is a significant negative link between growth and volatility.

The above mentioned descriptive analysis presents an unconditional positive relationship between growth and volatility in China, but maybe the relationship varies over time according to Figure 1 and Figure 2. Furthermore, the economic growth is considered to be determined by some important variables, such as initial income level, and initial human capital, among others. To investigate the real relationship between growth and volatility, we conduct a more formal regression analysis in the following sections.

4 Specifications and Results

This section examines the relationship between growth and volatility using both cross-sectional and panel regressions, and incorporating various control variables. First, a cross-sectional analysis is conducted using the provincial data over the whole period 1978–2008. A panel dataset for 30 provinces over six consecutive five-year sub-periods is then employed for panel regressions.

4.1 Cross-Sectional Analysis

We first begin with a cross-sectional analysis on the growth-volatility link, discussing the relationship between long-term growth and volatility over the last three decades for Chinese provinces. The seminal work of Ramey and Ramey (1995) shows a significant negative link between growth and volatility in a 92-country sample over the period 1962–1985. Kose, Prasad, and Terrones (2006) also provide a significant negative link in an 85-country sample over the period 1960–2000, a significant positive one for industrial countries, and a significant negative one for the developing countries. In contrast with the previous studies, we find an unconditionally significant (at the 1% level) and positive link of 0.59 between growth and volatility among Chinese provinces (see column 1 of Table 2).

Further attention is given to the relationship within different regions. Columns 2 to 4 of Table 2 report the unconditional link within eastern, central, and western regions, respectively. A positive but insignificant growth-volatility link is observed within all three regions. We then introduce the interaction of volatility with regional dummies in column 5. The interactions show a significant positive relationship between growth and volatility within eastern region, but an insignificant and weaker relationship within the other two regions. Therefore, an unconditional positive link between growth and volatility is observed in Chinese provincial sample, whereas the significance levels vary across different regions.

[TABLE 2 HERE]

In the studies of Ramey and Ramey (1995), Martin and Rogers (2000), and Kose, Prasad and Terrones (2006), some important factors are considered to determine growth. Based on Levine and Renelt (1992), a set of standard control variables are chosen. They are the initial per capita GDP, initial human capital, average share of investment in GDP, and the average population growth rate. In the previous cross-country studies, the initial per capita GDP always has a significant negative sign, indicating a conditional convergence. First, the initial human capital has a significant positive sign, indicating the importance of the human capital to economic growth. Second, the investment share has a positive sign, implying the important association of investment with growth. Lastly, the population growth has a negative sign. We simplify the Equation 1 into a cross-sectional specification by letting the period T be the whole reform era, and include the abovementioned four standard control variables in the regression specification. The results of cross-sectional regressions are reported in Table 3.

[TABLE 3 HERE]

Column 2 and 3 show that the initial income level, initial human capital, and population growth are associated with the economic growth, despite the fact that significance levels vary. Initial per capita GDP has a highly significant relationship with the economic growth at the 1% significance level, indicating a noticeable conditional convergence among Chinese provinces in the reform period. The initial human capital is positively linked with the economic growth, but its magnitude and significance level drop once other control variables are included. As expected, the population growth has a significant and negative link with growth. However, the average investment rate is insignificant in both specifications, an observation that may be inconsistent with the conventional view that investment is the driving force of the economic growth of China (Young, 1995).

We can find that after the accounting for the impact of standard control variables in growth literature, the link between growth and volatility still stays positive and significant. The coefficient decreases in columns 2 and 3 compared with the unconditional one. Taking column 3 for example, after controlling the four standard independent variables, the link between growth and volatility is positive and significant at the 1% significance level, reaching 0.468. Column 4 considers an alternative specification to column 3 using the initial values of investment rate and population growth rather than the average values. This specification takes into account the endogeneity concerns of using average values instead of the initial values. The growth-volatility link remains positive and significant at the 5% significance level. The conditional convergence, positive link of human capital, and negative link of population growth still hold, but their significance levels differ.

4.2 Panel Analysis

Since China has experienced a slight increase in economic growth and a significant drop in volatility in the second half of the reform period, a panel analysis of the relationship between growth and volatility is necessary to better understand the dynamics of this link. This section uses a provincial panel dataset for 30 provinces over six consecutive non-overlapping sub-periods. As stated in the data section, initial value, average value, and standard deviation are all calculated over each sub-period for each province.

[TABLE 4 HERE]

Similar to the cross-sectional analysis, we first look at the unconditional link between growth and volatility in the panel dataset. Table 4 shows the unconditional relationship for all provinces and within three regions. Controlling the effect of period dummies, we find a significant positive growth-volatility link among all provinces and a positive but insignificant one within each region. The column 5 of Table 4 introduces the interaction term of volatility and region dummies to the simple regression, and shows a similar result to that in cross-sectional analysis, a significant positive link within eastern region. The fact that the coefficient on volatility in the panel analysis is smaller than that in the cross-sectional analysis is noteworthy.

[TABLE 5 HERE]

The results of specifications with standard controls following Equation 1 are summarized in Table 5. In all specifications, the relationship between growth and volatility remains positive and significant. In addition, the coefficients are stable, at 0.39, when different sets of control variables are considered. However, some standard controls become insignificant, and even the coefficient signs are in contrast with the expected ones and with the coefficients in cross-sectional regressions. The initial income level remains negative but less significant. Initial human capital has a negative and insignificant link with economic growth in the panel regression, an observation that is also reported by Hao (2006), who likewise employs the average schooling years as the measure of human capital. When using alternative human capital measure, for instance, the second school enrollment rate, the human capital shows a significant positive link with economic growth (Hasan, Wachtel and Zhou, 2009). Taking column 3 as the benchmark specification, the investment rate is positive but insignificant, whereas the population growth is significantly and negatively associated with economic growth. Lastly, we use the initial conditions of investment rate and population growth to substitute for the corresponding mean values in column 4. The volatility remains positive and significant, and the coefficient is fairly stable.

Notably, the OLS estimates in the panel regression of Table 5 can be biased and inconsistent with the presence of dynamic effects and simultaneities. Since economic growth and volatility may be simultaneously determined by the same factors and shocks, the dynamic effects should be considered. Arellano and Bond (1991), Arellano and Bover (1995), and Blundell and Bond (1998) develop the first-differenced GMM approach and system GMM techniques to solve these problems. Furthermore, Blundell and Bond (2000), and Bond (2002) argue that the first-differenced GMM approach can be biased in the case of weak instruments and finite samples, an observation that is the very case of our study. The cross-provincial panel sample has a finite sample with more provinces and less periods. Therefore, we use the system GMM approach to account for the simultaneity problem of our OLS regressions.[71] Moreover, either the one-step or two-step approach of system GMM estimation can be used. Usually, both of them are reported since there is a downward bias in the computed standard errors in the two-step estimation. However, with the finite sample correction of Windmeijer (2005), the standard errors in the two-step estimation are quite accurate, and the two-step estimation with correction seems modestly superior to one-step estimation. In this study, the two-step system GMM estimation with the correction of Windmeijer (2005) is our main focus, and the results of one-step approach are also reported as a reference.

In the system GMM estimation, two tests are employed to verify the validity of instruments. The first one is the Hansen test of over-identifying, which tests the overall validity of instruments. The second one is the autoregressive (AR) test, which tests the presence of second-order serial correlation in the first-differenced error term.[72]

[TABLE 6 HERE]

The estimation results using the system GMM approach are shown in Table 6. Column 1 reproduces the benchmark result in Table 5, and columns 2 to 5 summarize the GMM estimations. First, we treat the volatility as an endogenous variable, the standard controls to be pre-determined, and the period dummies as exogenous. Since the investment rate and population growth in standard controls are measured by their period average values, endogeneity issues may emerge. Therefore, we also substitute the period

[71] In the system GMM approach, the instruments for regression in levels are the lagged differences of the corresponding variables, whereas the instruments for regression in differences are the lagged levels.

[72] The AR tests allow the differenced error term to be first-order serially correlated, but the second-order serial correlation violates the basic assumption of GMM approach.

average by their initial values in the GMM estimations. These results are shown in columns 2 to 5.

Moreover, we also take into account the consideration that the standard deviation of high economic growth may be naturally large. We introduce a lagged value of average economic growth into the regression models to control the consideration above. The OLS and system GMM estimations are reported in columns 6 to 10. The basic specification settings of columns 6 to 10 are the same with those of columns 1 to 5.

All estimations satisfy the basic test of the system GMM specifications. The Hansen tests suggest no sign of over-identification, while AR tests indicate the there is no evidence of second-order serial correlations. All GMM estimations in Table 6 show a significant positive relationship between growth and volatility with a relatively stable coefficient. When lagged average economic growth is included in the specifications, the volatility remains more positive and significant than that in the 1% significance level, indicating a pronounced improvement in significance level compared with the results without lagged average economic growth. Moreover, the magnitude of coefficient on volatility slightly decreases, from more than 0.60 to less than 0.55.

In this section, we use the system GMM approach to deal with the endogeneity and simultaneity issues of volatility, and find a statistically significant and positive growth-volatility link, suggesting that the positive effect of aggregate volatility on average economic growth is evident for Chinese provinces.

5 Robustness of the Results

In this section, we examine the robustness of our main finding about a significant positive link between growth and volatility among Chinese provinces. First, several alternative regression frameworks are considered to take into account some potential misspecification problems that may be associated with our main results in the previous section. Subsequently, several additional control variables are included in the regression to check whether the benchmark results are robust. Moreover, two alternative measures of volatility are employed to reexamine the growth-volatility link. Lastly, two alternative methods of provincial panel sample construction, namely, dividing the reform period either into two sub-periods or into three sub-periods, are considered.

5.1 Alternative Regression Frameworks

In this section, we turn to consider some problems associated with several potential misspecifications. The problems we are concerned here include the effects of provincial size, the effects of sample outliers, the omission of provincial fixed-effects, and the endogeneity problem. Tables 7 and 8 show the robustness regressions for cross-sectional and panel samples, respectively. Column 1 of both tables reproduces our benchmark results in the previous sections. Other columns show the results of robustness tests with alternative regression frameworks.

[TABLE 7 HERE]

[TABLE 8 HERE]

First, we take into account the effect of provincial size. Since both economy and population size of Chinese provinces notably vary, we should incorporate the provincial size effect using weighted regression models to verify whether our results are driven by large provinces. Columns 2 and 3 of both tables represent the results of weighted regression models, with GDP and population as the weight, respectively. The significant positive link between growth and volatility still holds in both cross-sectional and panel regressions. In cross-sectional regressions, all coefficients are relatively stable, whereas in the panel regressions, the initial human capital becomes negatively related with economic growth, and the investment turns to be positive but insignificant.

We also want to know whether our results are affected by sample outliers. Therefore, we employ the Quantile regression model, which uses median as a measure of central tendency. The column 4 of Tables 7 and 8 summarizes the results of Quantile regressions. The results of both cross-sectional and panel regressions indicate that the significant positive growth-volatility link persists and the coefficient is relatively stable compared with the benchmark specification.

Province-specific and time-invariant characteristics may not be captured by our control variables in benchmark specifications. As a result, we apply provincial fixed-effect model to the panel sample. The column 5 of Table 8 reports the result of provincial fixed-effect regression, which shows that the link between growth and volatility is still positive. However, both the significance level and coefficient magnitude drop, suggesting that the significant positive growth-volatility link may be associated with the provincial fixed-effect to some extent. After controlling the provincial fixed-effect, we find that the conditional convergence becomes much stronger and the investment share turns to be positively and significantly associated with economic growth.

Finally, we turn to the potential problem of endogeneity. In our benchmark specification of panel regressions, the volatility of economic growth may be endogenous, an observation that has been discussed in the system GMM estimations. In this section, we attempt to use instrumental variables (IV) to address this problem. The instruments for the volatility are the lagged volatility and the initial government size of the current period (Fatás and Mihov, 2001; Andres, Domenech and Fatás, 2008).[73] The column 6 of Table 8 shows the result of the Two-Stage Least Squares (2SLS) regression using the IV discussed above. The IV regression satisfies the over-identification restriction and the positive link between growth and volatility, which still significantly holds despite a slight decrease in its significance level. The magnitude of the coefficient on volatility is as large as those estimated in the system GMM estimations.

This section incorporates the effects of provincial size, sample outliers, province-specific characteristics, and potential endogeneity on our benchmark results. Our main finding of the positive growth-volatility link is robust to the potential misspecifications discussed in this section.

5.2 Additional Control Variables

The standard controls used in the benchmark specifications are based on previous cross-country studies, and maybe several important control variables are ignored in the case of China. This section considers several additional control variables that potentially affect the link between growth and volatility such as the initial values of provincial size (real GDP and population), government size (the share of government expenditure over GDP), and primary sector size (the GDP share of primary sector), as well as period average of financial depth (the share of total loan over GDP), privatization (the investment share of non-SOEs), trade openness (the share of total trade over GDP), and FDI (the share of FDI over GDP). Tables 9 and 10 summarize

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[73] Fatás and Mihov (2001) show that the larger the government size, the less volatile the economy is. Moreover, Andres, Domenech, and Fatás (2008) establish a model that generates a negative link between volatility and government size. In this section, the government size is measured in terms of the share of government expenditure in GDP.

the results of cross-sectional and panel regressions, respectively. The first column of both tables reproduces the benchmark results, and the other columns show the regressions results, considering different additional control variables.

[TABLE 9 HERE]

[TABLE 10 HERE]

In Table 9, we find that the initial province size, privatization level, and trade openness are positively and significantly correlated with the long-term economic growth of Chinese provinces. Table 9 shows that the cross-sectional positive link between growth and volatility is robust with the inclusion of additional control variables, although the magnitude of coefficient on volatility varies in some cases. For instance, when the initial population size is considered, the growth-volatility link becomes noticeably larger (column 3 of Table 9). This may be attributed to a significant and linear correlation between initial per capita GDP and the initial population size. Significantly, once the openness variable is controlled, the link between growth and volatility becomes insignificant although still positive. The magnitude of the coefficient on volatility also drops. We may suspect that the significant positive growth-volatility link is associated with the role of openness in the economic growth.

The panel regressions in Table 10 confirm show results similar to that of cross-sectional investigations. The initial province size, SOE reform, trade openness, and FDI are positively and significantly associated with economic growth. We also find a relatively stable and significant positive relationship between growth and volatility when considering additional control variables. Similar to Table 9, after controlling the variable of trade openness, the growth-volatility link turns to be less significant with a smaller coefficient, suggesting that trade openness may be one of the conduits for the significant link between growth and volatility. The issue is discussed in the next sections.

5.3 Alternative Volatility Measure

Our benchmark specifications employ the standard deviation of economic growth as the measure of volatility. Meanwhile, other measures are also considered to represent important features of macroeconomic volatility for a country or a region. For instance, Martin and Rogers (2000) use the standard deviation of the unemployment rate as an alternative measure of volatility.[74] In this section, two alternative volatility measures are used. The first one is inflation volatility representing another important aspect of macroeconomic instability, and it is measured as the standard deviation of Consumer Price Index (CPI). The second one is innovation volatility, which captures the volatility of technological progress, and it is measured as the standard deviation of TFP growth under the growth accounting framework. We discuss the growth accounting procedure briefly as follows.

Using the Cobb-Douglas production function, we suppose that the output Y is produced by the labor input L and capital services K, and the production function is constant return to scale with Hicks-neutral augmented technology A. The growth accounting procedure is described as:

$$Y = Af\left(L,K\right) = AL^{\alpha}K^{1-\alpha} \tag{2}$$

$$\dot{Y}_t = \dot{A}_t + \alpha_t\dot{L}_t + \left(1-\alpha_t\right)\dot{K}_t\,, \tag{3}$$

[74] For Chinese data, the employment and unemployment statistics are fairly incomplete and have poor quality. Particularly, the statistical unemployment, which apparently underestimates the real unemployment, is only the registered unemployment in urban areas.

where $\dot{Y}_t$, $\dot{L}_t$, $\dot{K}_t$, and $\dot{A}_t$ indicate the growth rates of GDP, labor, capital, and TFP, respectively. For provincial panel data, the labor input is measured as the total employment,[75] the capital input is estimated according to the Perpetual Inventory Methods by the authors,[76] and the output elasticity of labor α is calculated as the share of labor compensation in GDP.

[TABLE 11 HERE]

Table 11 shows the results of cross-sectional regressions using alternative volatility measures. Column 1 reproduces the benchmark results, while columns 2 to 4 and columns 5 to 7 summarize the regression results using the standard deviation of CPI and that of TFP growth as the measure of volatility, respectively. A positive relationship between growth and both alternative volatility measures are found, although the link is insignificant in most specifications. The regressions with standard control variables (columns 4 and 7) suggest a weakly significant and positive growth-volatility link, with conditional convergence and negative relationship between population growth and economic growth. Therefore, we cannot conclude a positive growth-volatility link in cross-sectional regressions with alternative volatility measures.

[TABLE 12 HERE]

[TABLE 13 HERE]

Tables 12 and 13 produce the results of panel regression using alternative volatility measures. Columns 1 to 3 of both tables duplicate the benchmark

[75] We adjust the employment data for Jiangsu, Shandong, Hubei, and Qinghai because there is a significant statistical break in their employment data series in 1990, 1995, 1990, and 1990, respectively. The adjustment method is based on the approach used by Holz (2009) to adjust the national employment data.

[76] The base year of capital estimation is 1952. We use the gross fixed capital formation as the investment series, and let the depreciation rate be 0.09.

specifications, including the results of fixed-effect (column 2) and two-step system GMM regressions (column 3). Other columns show the regression results using alternative volatility measures. From Table 12, we can see a significant positive relationship between growth and inflation volatility, whether using standard, fixed-effect, or two-step system GMM estimations. The initial income level has a negative sign but not always significantly. Investment and population growth have expected signs although significance levels differ. The results in Table 13 are similar to those in Table 12, indicating a significant positive link between TFP growth volatility and economic growth, with a conditional convergence, a positive link of investment, and a negative link of population growth with economic growth (see columns 4 to 7 of Table 13).

Therefore, using alternative measures of volatility, we can get a positive relationship between growth and volatility. The relationship is not always significant in cross-sectional regressions, but highly significant in panel regressions. The results also show a conditional convergence and positive growth-investment link, but not always significantly. Population growth is statistically significantly associated with economic growth. The relationship between initial human capital and growth is ambiguous, sometimes with a significant negative coefficient, just similar to the results found in the study by Hao (2006).

5.4 Alternative Period Division Methods

In the benchmark specifications, we divide the reform period into six non-overlapping, five-year sub-periods to construct the provincial panel sample. In this section, we test the robustness of the benchmark results using different methods of sub-period division. The first alternative method is to split the whole period into two sub-periods, namely, 1978–1992 and 1993–2008. This division method is meaningful because after Deng Xiaoping addressed his historic South Tour speech in 1992, China has accelerated its reform toward the market-oriented economy. Furthermore, the first essay of the author's PhD dissertation also provides strong evidence that there is a structural break in the variance of China's economic growth in the years 1992 and 1993 (Zhang, 2011a). The second method divides the last three decades into three sub-periods, namely, 1978–1987, 1988–1997, and 1997–2008.

We summarize the main regression results using two-period sample and three-period sample in Table 14 and Table 15, respectively. In both tables, the results of regressions with standard controls, weighted regression, Quantile règression, provincial fixed-effect regression, and regression with instrumental variables are shown.

[TABLE 14 HERE]

[TABLE 15 HERE]

Using the two-period sample, Table 14 presents a significant positive link between growth and volatility, except for the fixed-effect specification, in which a positive link is still observed although said link is insignificant. Moreover, the coefficient on volatility is noticeably smaller in fixed-effect regression. Column 7 suggests that the positive growth-volatility link in benchmark specifications partly can be attributed to the province fixed-effects, which are not captured in our benchmark results. We further separately run the benchmark regressions for each of the two sub-periods. The positive and significant growth-volatility link holds in each of the two sub-periods, but the magnitude of the coefficient on volatility substantially differs.[77] We suspect that it may be associated with the pronounced decline in volatility after 1992 for most provinces.

When considering the three-period panel sample, the results are more inspiring. Table 15 illustrates a significant and positive growth-volatility link, and the coefficient on volatility is relatively stable, except for the fixed-effect and IV specifications. In the column 7 of fixed-effect specification, the growth-volatility link is significant while the coefficient remarkably drops.

6 Discussions

Our study presents a significant positive link between growth and volatility among Chinese provinces for both cross-sectional and panel samples. Furthermore, the robustness tests confirm this result after taking into account the effects of alternative regression frameworks, additional control variables, alternative volatility measures, and alternative sub-period division methods. However, our results are different from those of Ramey and Ramey (1995), Martin and Rogers (2000), and Kose, Prasad and Terrones (2006). Their studies show a significant negative relationship between growth and volatility for the cross-country sample, as well as for the developed countries sample. Martin and Rogers (2000) find a positive link for the developing countries, but it is an insignificant one. The significant positive relationship we find for samples of Chinese provinces may confirm the conclusion made by Martin and Rogers (2000) that the negative relationship between fluctuation and growth is robust only for developed countries.

[77] In the benchmark regression with standard control variables, the coefficients on the volatility are 0.49 and 1.12 for the period 1978–1992 and 1993–2008, respectively. Both of them are significant, at least at the 5% level.

In China, why is volatility positively associated with the economic growth? We make some preliminary efforts to investigate this issue in this section. Theoretically, if an economy is facing the choice between technologies with high variance and high expected returns, and those with low variance and low expected returns, it results in a positive link between growth and volatility (Black, 1987). Moreover, in the case of creative destruction, the opportunity cost of productivity-improving activities drops in recession, and the business cycles and volatility may have a positive effect on long-term economic growth (Aghion and Howitt, 1992; Caballero and Hammour, 1996). Imbs (2007) argues that a positive relationship between growth and volatility can be found in the samples at the sectoral level, but when the link is examined at the aggregate level, it turns out to be negative.

In this section, we attempt to discuss some possible explanations and relevant issues of the significant positive growth-volatility link in the context of the Chinese economy. We discuss how the volatility is associated with the growth rates of demand components of GDP, so that we may find interesting results about the link between volatility and welfare issues, e.g. private consumption growth. We also investigate the growth-volatility link at the sectoral level using a dataset covering 12 economic sectors of Chinese provinces. A disaggregate discussion can be an important complement to the aggregate study as what Imbs (2007) suggests. Analyses are conducted to discuss possible conduits for the positive growth-volatility link. Lastly we propose an analytical framework to explain the distinct growth-volatility link in China and further try to provide some empirical evidence.

6.1 Volatility and Demand Components of GDP

Some studies argue that the welfare cost of business cycles is fairly large in developing countries (Pallage and Robe, 2003; Barlevy, 2004), including China (Chen and Zhou, 2006). In this section, we empirically examine the relationship between volatility and consumption growth for Chinese provinces. Particular attention is given to the differences of this link between rural and urban consumption growth. Certainly, in terms of the demand side of GDP, we can also investigate the relationship between volatility and investment growth.

[TABLE 16 HERE]

First, we run the regression of the growth rate of investment or consumption on the aggregate growth volatility and other standard control variables. The results are shown in columns 1, 3, 5, and 7 of Table 16. We then substitute the aggregate growth volatility by the volatility of corresponding GDP demand component,[78] and conduct the regressions again. The results are presented in columns 2, 4, 6, and 8 of Table 16. We find that there is no significant link between investment growth and either aggregate growth volatility or investment growth volatility (columns 1 and 2 of Table 16),[79] a finding that is different from the positive and significant link between capital growth and volatility. The aggregate private consumption growth also has no significant relationship with either the output volatility or private consumption volatility (columns 3 and 4 of Table 16).

Moreover, it is interesting to find noticeable difference in the links of volatility with urban consumption growth and rural consumption growth. Columns 5 to

[78] The volatility of the corresponding GDP demand component is measured as the standard deviation of growth rate of corresponding demand component. For instance, the volatility of investment is calculated as the standard deviation of investment growth.

[79] The regression results of investment share in GDP on the same standard control variables are similar to those of investment growth, showing an insignificant positive link between investment share and volatility.

9 show that the volatility variables are negatively and significantly associated with rural consumption growth, but are positively and significantly associated with urban consumption growth. Urban households are likely to benefit from a volatile economy, whereas the rural households are not. This may be associated with the increasing rural-urban income inequality of China in recent decades. China is one of the countries with the highest degrees of rural-urban income inequality, and the inequality is still increasing although the economic growth remains high (Yang, 1999; 2002). As a result of urban-biased policies and institutions, urban residents remarkably benefit more than rural residents do from the economic growth (Yang, 1999), but lose less than their rural counterparts do during external shocks and economic contractions as they have relatively well-built welfare system. Since aggregate volatility has positive effect on economic growth, the urban residents in a province with higher volatility earn more and consume more. However, because of the less developed social security system, the rural residents consume less than the urban residents do with the consideration of precautionary savings. On the other hand, rural residents benefit less from high growth, but lose more in an instable economic environment. Therefore, it may lead to a positive relationship between volatility and urban consumption growth, and a negative one between volatility and rural consumption growth.

6.2 Volatility and Growth at Sectoral Level

Imbs (2007) uncovers a significant positive growth-volatility link at the sectoral level across countries, and analytically argues that the sectoral link between growth and volatility is irrelevant to the aggregate link, which is determined by the country-specific component of aggregate volatility. Volatile sectors command high investment rate and hence high value-added growth.

Given the significant results for cross-country sample and reduced OECD sample, what would it be for the developing countries, in particular for the Chinese economy? This section investigates the growth-volatility link at the sectoral level for Chinese provinces, and then discusses the possible channel of sectoral volatility on growth.

Our sectoral panel data consists of nominal sectoral value-added and real sectoral value-added growth of 12 economic sectors[80] for 30 Chinese provinces over the years 1978–2002 since we only have consistent sectoral data of 12 sectors under the industry classification GB1994 for that period. The industry classification after 2002 has been substantially changed into the new GB2002. The sectoral value-added data for the years 2003–2008 are inconsistent with those for the period 1978–2002. We mainly draw data from the *Data of Gross Domestic Product of China 1952–1995* and *Data of Gross Domestic Product of China 1996–2002*, and make necessary adjustments to obtain a consistently defined dataset for 12 economic sectors.

We use the following panel specification to examine the effects of sectoral volatility on growth:

$$g_{ij,T} = \beta\sigma_{ij,T} + \delta X_{ij,T} + \alpha_i + \alpha_j + \alpha_T + \varepsilon_{ij,T} \qquad (4)$$

where $g_{ij,T}$ is the average growth rate of the sectoral value-added of sector i in province j over period T, $\sigma_{ij,T}$ is the volatility variable measured as the standard deviation of sectoral value-added growth of sector i in province j over

[80] The 12 economic sectors are: one primary sector, two secondary sectors, including (1) industries and (2) construction, and nine tertiary sectors, including (1) transport, storage, post, and telecommunication; (2) wholesale and retail trade, and catering; (3) finance and insurance; (4) real estate; (5) health, sports, and social welfare; (6) education, culture, arts, radio and television broadcasting; (8) scientific research and technical services; (9) government agencies and social organizations. Tibet is excluded to keep sectoral analysis consistent with the aggregate one.

period T, $X_{ij,T}$ is a vector of control variables, α_i is a sector specific intercept representing sectoral fixed-effect, α_j is the time-invariant province, α_T is the period dummy, and $\varepsilon_{ij,T}$ is the residual term. In this section, the value-added is converted to be at constant 2000 price, and the value-added growth is estimated as the log difference of the real value-added.

As Imbs (2007) argues, the sector grow faster is initially the smaller one due to diminishing return on capital. The initial sectoral size (logarithm value), therefore, should be included in the specification. Moreover, due to the concerns of transition dynamics and comparative advantage, the initial sectoral value-added share in GDP is also considered a control variable. Therefore, we run the regression of average sectoral value-added growth on the sectoral value-added volatility, initial sectoral size, initial sectoral value-added share, sector dummy, province dummy, and period dummy to examine the growth-volatility link at the sectoral level.

[TABLE 17 HERE]

The regression results are shown in Table 17. The cross-sectional sample, two-period sample, three-period sample, and six-period sample are all considered.[81] We can find that the coefficients on volatility are overwhelmingly positive and significant for all the samples, no matter what control variables are included. The coefficient on sectoral volatility is relatively stable in terms of magnitude. Table 17 provides some evidence of conditional convergence. After the sector, province, and period fixed-effects are controlled, an initially smaller sector in terms of absolute size is inclined to grow faster. However, an initially relatively

[81] Since we only have the sectoral data for the period 1978–2002, the cross-sectional sample corresponds to the data for the period 1978–2002, the two-period sample corresponds to 1978–1992 and 1992–2002, the three-period sample corresponds to 1978–1987, 1988–1997, and 1998–2002, and the six-period sample actually have five 5-year periods.

larger sector tends to grow faster than those initially relatively smaller sectors, an observation that may be attributed to comparative advantage. Our results suggest that the initial conditions are important in explaining the sectoral value-added growth, and confirm the potential importance of transitional dynamics in explaining the significant positive link between growth and volatility at the sectoral level.

Our discussions in the previous sections show that the positive link between growth and volatility may be associated with the conduit of capital deepening, but not significantly through investment. The argument above seems controversial, and in fact it is possible that the investment allocation across sectors does not coincide with the aggregate results. Following Martin and Rogers (2000) and Imbs (2007), we investigate the relationship between sectoral investment rate and the sectoral volatility of value-added growth by running the regression of sectoral investment rate, which is measured as the investment share in sectoral value-added, on sectoral volatility, and other control variables as well as the standard set of fixed-effect dummies.

The sectoral investment data are only available for the three main economic sectors (the primary, secondary, and tertiary sector), but not for the 12 economic sectors discussed in this section. We consider the sectoral gross fixed capital formation as the sectoral investment. The sectoral investment data are available for the period 1978–2002 for the three main sectors of Chinese provinces.[82] Although only the data for the three main economic sectors are

[82] The *Data of Gross Domestic Product of China 1952–1995* provides the data on sectoral gross fixed capital formation in nominal terms for 30 provinces without Chongqing. The *Data of Gross Domestic Product of China 1996–2002* summarizes the nominal sectoral investment data for 31 provinces. The sectoral investment data after 2002 are not available. The data for Chongqing, Hainan, and Guangdong are incomplete over the last three decades. Therefore, we lost several observations in panel samples.

available, it can still provide important evidence to the investment-volatility link at the sectoral level.

[TABLE 18 HERE]

Table 18 summarizes the regression results of the investment-volatility link for cross-sectional and panel samples. The volatility is significantly and positively correlated with the sectoral investment share in the three-period and six-period samples. The investment-volatility links in the cross-sectional sample and two-period samples are still positive but insignificant,[83] suggesting that investment share is higher in volatile sectors. This finding is consistent with the results of Imbs (2007) showing that the more volatile economic activities command higher investment rate and hence higher sectoral growth. Our results in Table 18 also indicate that the investment share of the secondary and tertiary sectors are significantly and sizably greater than that of the primary sectors, an observation that is consistent with the positive investment-volatility link given the fact that the secondary and tertiary sectors are more volatile than the primary sector. Moreover, to test the robustness of our results, we also examine the sectoral growth-volatility relationship using a panel dataset comprised of value-added data of the three main economic sectors. The results indicate that the relationship between growth and volatility is significant and positive for the three-sector samples, consistent with our results in the investigation using the 12-sector samples.

Our results imply a significant positive growth-volatility link and investment-volatility link at the sectoral level for Chinese provinces. Among the three

[83] Since we only have sectoral investment data for the period 1978–2002, the cross-sectional sample corresponds to the data for the period 1978–2002, the two-period sample corresponds to 1978-1992 and 1992-2002, the three period sample corresponds to 1978–1987, 1988–1997, 1998-2002, and the six-period sample actually have five 5-year periods.

main economic sectors, a more volatile sector is likely to command higher investment rate, and consequently higher value-added growth. This is consistent with the results uncovered for the cross-country sample and OECD sample by Imbs (2007). Imbs (2007) analytically show that the aggregate growth-volatility relationship is irrelevant to the disaggregate link at the sectoral level if the number of sectors is large. The growth-volatility link is only determined by the country specific component of the aggregate volatility on growth. In our case of the 12-sector sample of Chinese provinces, the number of sectors we discussed is large enough for us to ignore the effect of idiosyncratic component. Therefore, the province-specific component of the aggregate volatility dominates the aggregate growth-volatility link, and turns out to be positively correlated with the aggregate growth.

6.3 Conduit for the Growth-Volatility Link

Several theories argue that the volatility affects economic growth through the channel of investment, either negatively or positively (Caballero, 1991; Aizenman and Marion, 1993). However, Ramey and Ramey (1995) state that the significant negative growth-volatility link in cross-country samples does not come from the investment channel.

In our benchmark specifications in Table 3 and Table 5, the coefficient on volatility remains stable and significant after the investment share is controlled. The investment share is insignificantly associated with economic growth, suggesting that the investment share is not empirically important in the positive link between volatility and economic growth among Chinese provinces. We should be cautious in making conclusions since China has experienced a rapid shift from a planned economy to a market economy, and its investment structure has dramatically changed. For instance, the average share of SOEs in the total investment for Chinese provinces was 90.9% in 1978, whereas it became 32.7% in 2008. The role of non-SOEs in economic growth becomes increasingly important and contributes a significant part to the economic growth of China. Therefore, we should dig deeper to study the investment channel of growth-volatility link.

This section investigates the relationship between volatility and investment, including aggregate investment, non-SOE investment, and FDI. First, we examine whether the volatility is significantly associated with aggregate investment by regressing the average aggregate investment share on volatility and standard control variables. Columns 2 and 3 of Table 19 show the results of the regression of average share of GFCF in GDP, which was used in our benchmark specifications to measure the investment share. We also use the total investment in fixed assets as an alternative measure of investment for the robustness test. The results are shown in columns 4 and 5 of Table 19. We can find that both the unconditional and conditional relationship between aggregate investment share and volatility are positive but insignificant. Thus, there is little evidence that the aggregate investment share is associated with volatility. Therefore, we may say that the positive effect of volatility on economic growth cannot be explained by the aggregate investment channel.

[TABLE 19 HERE]

However, when we look at the relationship between the non-SOE investment share in GDP and the FDI share in GDP, the results are interesting and different. Columns 6 and 7 summarize the regression results of non-SOE investment share, whereas columns 8 and 9 report the regression results of FDI share. Columns 6 to 9 show that both the non-SOE investment share and FDI share are positively and significantly related to the volatility. A more volatile province commands a higher GDP share of non-SOE investment and FDI.

Moreover, Table 10 illustrates that non-SOE investment share and FDI share play an important role in the economic growth of Chinese provinces. After either of these two variables is controlled, both the magnitude and significance level of the coefficient on volatility drop to some degree. Therefore, there is some evidence that the positive growth-volatility link partly flows through the non-SOE investment and FDI channels. This result is linked to the risk-return nexus, indicating that a high risk investment commands a potential higher return, and the growth-volatility link turns to be positive. A province with higher volatility is economically attracting non-SOE investment and FDI, and commands a higher economic growth. Only the investments from non-SOE sectors and foreign capital are the important conduits between volatility and growth.

Lastly, we discuss the role of trade openness in the growth-volatility link. The robustness tests in Table 10 indicate that once the trade openness (measured as the GDP share of total trade) is controlled, the significance level and magnitude of the coefficient on volatility remarkably decline. Moreover, we find that the trade openness is positively and significantly correlated with economic growth, suggesting an important role of trade openness in explaining economic growth. Clearly, the link between volatility and trade openness as the province with higher trade dependence may be more vulnerable to external shocks and be more volatile. We regress the volatility on trade openness and other standard control variables. Regression results show that trade openness is positively related to volatility at the 10% significance level. In this section, we find that trade openness is positively correlated with economic growth and with volatility. Given the results in Table 10, we may argue that the positive growth-volatility link among Chinese provinces may be to some degree explained by the role of trade openness. A more open province with high level of trade dependence is prone to enjoy higher economic growth, and is likely to suffer more external shocks. Therefore, a positive link between growth and volatility emerges.

6.4 Why China Differs from International Evidence

This study provides robust evidence of a positive link between growth and volatility, which is measured by the standard deviation of per capita GDP growth over a period and substantially different from the international empirical result of a negative one. Why is the result for China distinct from international evidence? In this section, we propose a simple analytical framework to explain the different results of growth-volatility link between the Chinese case and cross-country evidence. According to the studies on the relationship between growth and volatility, for simplicity, the aggregate growth volatility can be considered a combination of a positive component and a negative component. The former is associated with some factors positively linked with growth, i.e. risk-return and creative destruction (Black, 1987; Caballero and Hammour, 1996; Imbs, 2007), whereas the latter is associated with some factors negatively linked with growth, i.e. policy uncertainty and political instability (Aizenman and Marion, 1993; Alesina et al., 1996; Acemoglu et al., 2003; Fatás and Mihov, 2003a). We summarize the abovementioned concepts as follows:

$$\sigma = \alpha_0 + \alpha_1\sigma_1 + \alpha_2\sigma_2 + \varepsilon_\sigma \qquad (5)$$

$$g = \beta_0 + \beta_1\sigma_1 + \beta_2\sigma_2 + \varepsilon_g , \qquad (6)$$

where σ is the aggregate growth volatility, g is the average economic growth, σ_1 is the positive volatility component, σ_2 is the negative volatility component, and ε_σ and ε_g are the iid residual terms.

In terms of our analytical framework, we have $\alpha_1 > 0$, $\alpha_2 > 0$, $\beta_1 > 0$, and $\beta_1 < 0$. In the regression specification about the growth-volatility link, we regress the average economic growth on the aggregate volatility measure, mainly because either we cannot perfectly separate the two volatility components, or the aggregate relationship is of great research interest. We have a simple regression as follows:

$$g = \gamma_0 + \gamma_1 \sigma + \varepsilon_V . \tag{7}$$

Therefore, the coefficient on volatility can be simply obtained using the following equation:

$$\begin{aligned} \gamma_1 &= \frac{\operatorname{cov}(\sigma, g)}{\operatorname{var}(\sigma)} = \frac{\operatorname{cov}(\alpha_0 + \alpha_1\sigma_1 + \alpha_2\sigma_2 + \varepsilon_\sigma, g)}{\operatorname{var}(\alpha_0 + \alpha_1\sigma_1 + \alpha_2\sigma_2 + \varepsilon_\sigma)} \\ &= \frac{\alpha_1 \operatorname{cov}(\sigma_1, y) + \alpha_2 \operatorname{cov}(\sigma_2, y)}{\alpha_1^2 \operatorname{var}(\sigma_1) + \alpha_2^2 \operatorname{var}(\sigma_2)} = \frac{\alpha_1\beta_1 \operatorname{var}(\sigma_1) + \alpha_2\beta_2 \operatorname{var}(\sigma_2)}{\alpha_1^2 \operatorname{var}(\sigma_1) + \alpha_2^2 \operatorname{var}(\sigma_2)} \end{aligned} \tag{8}$$

The negative volatility component, i.e. policy uncertainty and political instability, is mostly stemming from the institutional environment of an economy (Aizenman and Marion, 1993; Fatás and Mihov, 2003a; Mobarak, 2005).The institutional factors are fundamental and dominant in long-term economic growth across countries, and there are substantial variances in institutional environment and instability (Acemoglu et al., 2003). We suspect that in cross-country samples, the usually unobserved variance of the negative volatility component arising from heterogenous institutional factors is much more pronounced than that of the positive volatility component, that is, $\operatorname{var}(\sigma_1)/\operatorname{var}(\sigma_2) \approx 0$. As a result, we have:

$$\gamma_1 = \frac{\alpha_1\beta_1 \operatorname{var}(\sigma_1)+\alpha_2\beta_2 \operatorname{var}(\sigma_2)}{\alpha_1^2 \operatorname{var}(\sigma_1)+\alpha_2^2 \operatorname{var}(\sigma_2)} = \frac{\alpha_1\beta_1 \operatorname{var}(\sigma_1)/\operatorname{var}(\sigma_2)+\alpha_2\beta_2}{\alpha_1^2 \operatorname{var}(\sigma_1)/\operatorname{var}(\sigma_2)+\alpha_2^2} \approx \frac{\beta_2}{\alpha_2} < 0 . \tag{9}$$

Therefore, with the assumption of the dominant role of the variance of the negative volatility component and institutional factors in the aggregate volatility in cross-country samples, we can have a negative relationship between growth and volatility as revealed by Ramey and Ramey (1995), Martin and Rogers (2000), and Kose, Prasad and Terrones (2006).

However, in the case of Chinese provincial sample, despite the differences in local governments' economic policies, the primary institutional factors, i.e. political system, history and culture background, and social structure, are basically identical among Chinese provinces. The variance of aggregate volatility may mainly reflect the variation of positive volatility component, such as risk-return nexus. Therefore, we assume that $\operatorname{var}(\sigma_2)/\operatorname{var}(\sigma_1) \approx 0$, and the growth-volatility link should be:

$$\gamma_1 = \frac{\alpha_1\beta_1 \operatorname{var}(\sigma_1)+\alpha_2\beta_2 \operatorname{var}(\sigma_2)}{\alpha_1^2 \operatorname{var}(\sigma_1)+\alpha_2^2 \operatorname{var}(\sigma_2)} = \frac{\alpha_1\beta_1 + \alpha_2\beta_2 \operatorname{var}(\sigma_2)/\operatorname{var}(\sigma_1)}{\alpha_1^2 + \alpha_2^2 \operatorname{var}(\sigma_2)/\operatorname{var}(\sigma_1)} \approx \frac{\beta_1}{\alpha_1} > 0 \tag{10}$$

As a result, the reason why the growth-volatility link for China is so distinct from the cross-country result may be attributed to the relative importance of the variance of positive volatility component in the variance of aggregate volatility. Due to roughly homogenous institutional factors among Chinese provinces, the growth-volatility link may be mainly determined by the relationship between growth and positive volatility component, for instance, high risk commanding high investment and hence high economic growth. In particular, for Chinese provinces, only the channels of non-SOE investment and FDI matter.

6.5 Growth and Different Volatility Components

As stated in the previous section, the positive and negative components of aggregate volatility are considered to have different effects on economic growth. The negative volatility component arising from institutional factors, such as policy uncertainty and political instability, has a detrimental influence on long-term economic growth (Aizenman and Marion, 1993; Alesina et al., 1996; Acemoglu et al., 2003; Fatás and Mihov, 2003a). Some also argue that only the unexpected volatility, which is measured as the volatility of the residual from a growth forecasting equation, has a detrimental effect on growth, while the expected volatility, which is considered as the predicted volatility, is good for growth (Ramey and Ramey, 1995; Rafferty, 2005). The unexpected and expected volatility reflect the uncertainty effect and opportunity-cost effect, respectively. If firms can predicate the demand on their products well, they can take the advantage of recessions, in which the opportunity-cost of productivity enhancing activities is low, to increase the long-term growth (Aghion and Howitt, 1992; Rafferty, 2005). Therefore, the expected volatility is associated with the opportunity-cost effect and creative destruction consideration.

We cannot perfectly separate and measure the two volatility components, but at least we can roughly examine the different effects of these two components and their relative importance from a specific perspective, i.e. the expected volatility and policy volatility reflecting the positive and negative components, respectively.

Following some seminal efforts (Ramey and Ramey, 1995; Rafferty, 2005), we first estimate a growth forecasting equation for each province to derive predicated and residual values of provincial economic growth over the reform period. Then the expected and unexpected volatility is calculated as the standard deviation of the predicated and residual economic growth over a specific period, respectively. The forecasting equation for the GDP per capita growth includes a constant, one lag of GDP per capita growth, one lag of CPI, one lag of log value of GDP per capita, a linear time trend, and the square of time trend. The forecasting equations for Chinese provinces have adjusted R^2 ranging from 0.10 to 0.87. We consider the expected volatility reflects part of positive volatility component.

In the second essay of the author's PhD dissertation, fiscal policy volatility and investment policy volatility are introduced in the context of the Chinese economy (Zhang, 2011b). Discretionary fiscal policy and undesired investment policy are the corresponding policy components deviating from the current macroeconomic conditions (Caballero, Engel and Haltiwanger, 1995; Fatás and Mihov, 2003a; Qin and Song, 2009; Candelon, Muysken and Vermeulen, 2010). The aggressiveness in the use of discretionary fiscal policy or undesired investment policy is considered fiscal policy volatility or investment policy volatility, respectively. Policy volatility is found to be harmful to economic growth in the cross-country samples (Aizenman and Marion, 1993; Fatás and Mihov, 2003a). Here, the policy volatility is considered one kind of negative volatility component.

In this section, we re-visit the discussion of growth-volatility link for China incorporating measures of expected volatility and policy volatility. The basic specification also follows Equation 1, and the estimation results are reported in Table 20. Apart from OLS estimation, we conduct analyses using the two-step system GMM method, and consider the volatility measure as an endogenous variable, and all initial conditions as exogenous variables. Since the system GMM approach can basically provide unbiased estimates with the presence of dynamic effect, simultaneity, and endogeneity, the causal effect of volatility measure on economic growth is fairly reliable. All GMM estimations pass the Hansen over-identification tests and Arellano-Bond AR tests for serial correlation, indicating the validity of our specifications. The policy volatility variables for Chongqing are not available; hence, it is removed from the dataset. Therefore, we use a provincial panel sample covering 29 provinces over six consecutive non-overlapping sub-periods.

[TABLE 20 HERE]

We examine the relationship between growth and three categories of volatility measures. The first category concerns growth volatility, which has been studied in the previous sections. We also include two specific growth volatility measures in the analysis, e.g., the standard deviation of government expenditure growth and that of investment growth. These two growth volatility measures probably reflect the combination of a component responding to current macroeconomic conditions and a component representing policy instability, given the assumption that the discretionary policy component is exogenous to the current macroeconomic conditions. Columns 1 to 4 show the estimation results for the first category.

The second category uses the expected volatility, which is the standard deviation of predicted economic growth, to represent the positive volatility component. The estimation results are shown in columns 5 and 6. The third category employs two measures of policy volatilities, e.g., fiscal policy volatility and investment policy volatility. The fiscal and investment policy volatilities remove the effect of current macroeconomic conditions and represent the discretionary or undesired policy components deviating from the aggregate economic circumstance. The estimation results are summarized in columns 7 to 10.

The first two columns reproduce the same estimations in the previous sections using the data without Chongqing, and show that the aggregate growth volatility significantly and positively affects the economic growth.[84] Columns 3 and 4 report the results using government expenditure growth volatility and investment growth volatility, respectively. Both the volatility of government expenditure growth and investment growth positively affect economic growth, suggesting potentially important channels through which the growth volatility affects economic growth. Columns 5 and 6 illustrate the estimation results for expected volatility, and show that the expected volatility has significant positive effect on economic growth, consistent with the results revealed in the cross-country analysis of Rafferty (2005), as well as the theoretical inference of the opportunity-cost effect of volatility (Aghion and Howitt, 1992).

Columns 7 and 8 present the estimation results for fiscal policy volatility, while columns 9 and 10 are the estimation results for investment policy volatility. Columns 7 to 10 provide notably different results from those in columns 1 to 6 in terms of growth-volatility link, suggesting a significant detrimental effect of policy volatilities on economic growth. Both fiscal policy volatility and investment policy volatility curb the per capita GDP growth in China.

Moreover, we include both the expected volatility and policy volatility in the specification, and the results are shown in columns 11 to 13. The expected and policy volatilities are considered to represent part of positive and negative volatility components, respectively. When both volatility measures are considered, the expected volatility remains significant and positive. However, both fiscal policy volatility and investment policy volatility becomes insignificant, albeit still negative in columns 11 and 12. It indicates that the

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[84] Since we exclude Chongqing from our sample, we get qualitatively similar but not identical results in the previous sections.

volatility component leading to a positive growth-volatility link, the expected volatility in this case, dominates the aggregate volatility, although both the fiscal and investment policy volatilities have an independently detrimental effect on economic growth, as shown in columns 7 and 10.

The analyses in this section support the argument that the aggressiveness in the use of discretionary policy has negative consequences on economic growth (Fatás and Mihov, 2003a). More importantly, even though we find a positive effect of growth volatility on economic growth across Chinese provinces, it is still evident that the policy volatilities, which reflect the aggressiveness in the use of discretionary fiscal policy or in the promotion of undesired investment growth, are harmful to the economic growth of Chinese provinces. The aggregate relationship between growth volatility and economic growth may be determined by the volatility component that positively affects economic growth, for instance, opportunity-cost effect in creative destruction, the choice between sectors with high variance and high growth, and sectors with low variance and low growth, risk-return nexus, and unobserved common national shocks. A better institutional environment, which stems from stable and predictable policies of far-sighted local governments and benign interactions between government and market, is crucial to the long-term economic growth of China.

7 Conclusions

Although both positive and negative links between growth and volatility can be inferred from theoretical analyses, the negative link is still considered a conventional wisdom in empirical studies. The influential work of Ramey and Ramey (1995) documents a significant negative relationship between growth and short-term instability, which is measured by the standard deviation of economic growth rate for both a cross-country sample and industrial-country sample. Recent empirical studies also confirm this negative link using cross-country samples (Martin and Rogers, 2000; Kose, Prasad and Terrones, 2006). However, the growth-volatility link for developing countries is debatable (Martin and Rogers, 2000; Turnovsky and Chattopadhyay, 2003).

Our study extends the empirical investigation on the growth-volatility link in the context of a developing country, particularly China. We find a quite different result from the existing empirical studies on the relationship between growth and volatility. Among the Chinese provinces over the last three decades, a significant positive growth-volatility link is both unconditionally and conditionally evident with standard control variables. Moreover, the positive link is significant in both cross-sectional and panel samples, and robust to both OLS and GMM estimates.

We also conduct several robustness tests to verify whether the positive link still holds when potential factors affecting this relationship are taken into account. After considering the effects of provincial size, sample outliers, provincial fixed-effects, and the endogeneity issue, the growth-volatility link remains positive and significant in most cases. Furthermore, when several additional control variables, for instance, the initial values of provincial size, government size, primary sector size and average level of financial depth, privatization, and trade openness, are included in the benchmark specification, the positive link still holds and remains significant. We also employ alternative volatility measures to verify the robustness of our results. Using inflation volatility and TFP growth volatility as alternative measures, we obtain a positive insignificant growth-volatility link in the cross-sectional sample, but significant in the panel regressions. Lastly, alternative sub-period division methods are considered. The significant positive link found in the six-sub-period sample is also revealed in the two-period and three-period samples. All the robustness tests suggest a positive significant relationship between growth and volatility, despite the fact that the significance level and magnitude of the coefficient on volatility vary across different specifications.

Imbs (2007) argues that the aggregate investigation may hide important information at the disaggregate level. He also uncovers a significant positive relationship between growth and volatility at sectoral level. We follow his idea to examine the growth-volatility link at the disaggregate level from different perspectives.

First, it is interesting to find a striking feature showing a substantial discrepancy in the links of volatility with urban consumption growth and rural consumption growth. As a result of urban-biased policies and institutions (Yang, 1999), urban households benefit more in economic growth and lose less in economic instability than their rural counterparts do. Therefore, urban households can benefit from a volatile macro economy, which is associated with high economic growth, but the rural households cannot.

We then investigate the growth-volatility link at the sectoral level in the context of the Chinese economy, following Imbs (2007). Using a panel data of 12 economic sectors for 30 Chinese provinces over the period 1978–2002, we find a result on the growth-volatility link at the sectoral level in China similar to that in the study of Imbs (2007) for cross-country and OECD samples. There is an overwhelmingly positive and significant link between sectoral growth and sectoral volatility in China. The initial conditions are statistically significant at the sectoral level, indicating that the transitional dynamics is of great importance in understanding this link. Furthermore, we also find a significant positive link between sectoral investment share and volatility.

Similar to cross-country studies, a more volatile sector is prone to command higher investment share and higher sectoral value-added growth.

Moreover, we investigate the conduit for positive growth-volatility link by examining the relationship between volatility and investment, including aggregate investment, non-SOE investment, and FDI. There is little evidence that aggregate investment is an important channel through which volatility is positively associated with growth. However, it is evident that, rather than the aggregate investment, the non-SOE investment and FDI may be the important conduits for the positive growth-volatility link.

The positive growth-volatility link can be inferred from several theoretical considerations, for instance creative destruction during recessions, and the choice between sectors with high variance and high expected returns, and sectors with low variance and low expected returns, etc. It is strongly evident that growth and volatility are positively correlated at the sectoral level among Chinese provinces. More volatile sectors command higher investment rate and consequently higher sectoral growth. However, as Imbs (2002; 2007) argues, the component of aggregate volatility that is common across sectors and specific to economies dominates the aggregate link between growth and volatility. Column 6 of Table 8 partially confirms this argument. Once the provincial fixed-effect is controlled, both the significance level and coefficient magnitude of volatility decline substantially, although it is still significant at the 10% significance level. Another concern about the positive link at the aggregate level can be attributed to transitional dynamics, as Martin and Rogers (2000) suggest, showing that the volatility is negatively but insignificantly associated with the initial level of per capita GDP (as well as the initial GDP). Transitional dynamics may create a positive bias between growth and volatility; hence, we include the initial per capita GDP in the benchmark regression, but in which the effect of transitional dynamics may not be fully controlled.

Why is China so distinct from the cross-country samples regarding the relationship between growth and volatility? We propose a simple analytical framework to explain this discrepancy. The aggregate growth volatility can be considered a combination of a positive component and a negative component. The former is associated with some factors leading to a positive growth-volatility link, i.e. risk-return nexus. The latter reflects the role of some factors associated with a negative growth-volatility link, i.e. policy uncertainty, and may mainly stem from underlying institutional factors. We argue that in the cross-country sample, the negative component dominates the variation of aggregate volatility given the fundamental role and substantial variation of institutional factors across countries. In contrast, the basic institutional factors are roughly identical among Chinese provinces, and the variance of negative component arising from institutional factors is much less prominent than that of the positive component. Therefore, the aggregate relationship between growth and volatility mainly comes from the effect of positive volatility component, maybe through the channel of non-SOE investment and FDI.

To enrich the investigation of the abovementioned growth-volatility link and the analytical framework, this essay also examines the effects of expected volatility and policy volatility on economic growth. The expected volatility, which is measured as the standard deviation of predicable economic growth in a forecasting equation, has positive effect on economic growth. However, a strikingly different result showing that both fiscal policy volatility and investment policy volatility significantly tame economic growth is obtained. Once both policy volatility and expected volatility are included in the regression, the significance of policy volatility vanishes, whereas the expected volatility remains positive and significant. It suggests that the aggregate relationship between growth and volatility may be dominated by the volatility component leading to a positive growth-volatility link. More importantly, it also suggests that a predictable and stable policy environment is vital to the long-term economic growth of China.

Lastly, two notes should be mentioned. First, an interesting stylized fact that almost all provinces have experienced a significant decrease in volatility, whereas the average per capita GDP growth modestly increases or remains stable in the second half of the reform period (Zhang, 2011a), is observed.[85] We attribute this phenomenon to the common factors that affect all provinces and are not captured by the provincial variances. For instance, the more stable political environment, the more effective monetary policies, and other national macroeconomic determinants lead to lower volatility and long-term high average economic growth in the second half of the reform period. Moreover, for Canadian provinces and US states, the growth-volatility link is found to be either weakly positive or insignificant, which is also different from the cross-country evidence. It may suggest that the mechanisms of growth-volatility link across countries and across regions within a country are different. The latter highlights the importance of regional variances within a country since the national common factor is controlled. It is also discussed in the section 6.4 and 6.5 of this essay.

[85] For GDP growth, if we compare the provincial mean growth rate and its standard deviation between the periods 1978-1992 and 1993-2008, we find that all provinces show a decline in their growth volatility, and the changes in only five provinces are insignificant. On the other hand, all provinces, except Guangdong, Hainan, and Xinjiang, experience an increase in mean growth rate, while 12 provinces show a significant change. The basic pattern for the per capita GDP growth is similar.

Second, although we find a significant and positive relationship between growth and volatility, it should be noted that volatility and instability are disproportionally harmful for the poor people because the consumption smoothing opportunities are limited especially for the poor (Ravallion and Jalan, 1999; Mobarak, 2005). This essay also finds that in China, only the urban household consumption is positively correlated with growth volatility, whereas the consumption of rural household with lower income is negatively linked with growth volatility.

References

[1] Acemoglu, D., Johnson, S., Robinson, J. and Thaicharoen, Y. (2003). Institutional Causes, Macroeconomic Symptoms: Volatility, Crises and Growth. *Journal of Monetary Economics* 50(1): 49-123.

[2] Aghion, P., Angeletos, G. M., Banerjee, A. and Manova, K. (2010). Volatility and Growth: Credit Constraints and the Composition of Investment. *Journal of Monetary Economics* 57(3): 246-265.

[3] Aghion, P. and Howitt, P. (1992). A Model of Growth through Creative Destruction. *Econometrica* 60(2): 323-351.

[4] Aghion, P. and Saint-Paul, G. (1998a). Uncovering Some Causal Relationships Between Productivity Growth and the Structure of Economic Fluctuations: A Tentative Survey. *Labour* 12(2): 279-303.

[5] Aghion, P. and Saint-Paul, G. (1998b). Virtues of Bad Times: Interaction Between Productivity Growth and Economic Fluctuations. *Macroeconomic Dynamics* 2(3): 322-344.

[6] Aizenman, J. and Marion, N. (1993). Policy Uncertainty, Persistence and Growth. *Review of International Economics* 1(2): 145-163.

[7] Aizenman, J. and Marion, N. (1999). Volatility and Investment: Interpreting Evidence from Developing Countries. *Economica* 66(262): 157-1179.

[8] Alesina, A., Ozler, S., Roubini, N. and Swagel, P. (1996). Political Instability and Economic Growth. *Journal of Economic Growth* 1(2): 189-211.

[9] Andres, J., Domenech, R. and Fatás, A. (2008). The Stabilizing Role of Government Size. *Journal of Economic Dynamics and Control* 32(2): 571-593.

[10] Arellano, M. and Bond, S. (1991). Some Tests of Specification for Panel Data: Monte Carlo Evidence and An Application to Employment Equations. *Review of Economic Studies* 58(2): 277-297.

[11] Arellano, M. and Bover, O. (1995). Another Look at the Instrumental Variable Estimation of Error-components Models. *Journal of Econometrics* 68(1): 29-51.

[12] Barlevy, G. (2004). The Cost of Business Cycles under Endogenous Growth. *American Economic Review* 94(4): 964-990.

[13] Barro, R. J. (1991). Economic Growth in a Cross Section of Countries. *Quarterly Journal of Economics* 106(2): 407-443.

[14] Bernanke, B. S. (1983). Irreversibility, Uncertainty, and Cyclical Investment. *Quarterly Journal of Economics* 98(1): 85-106.

[15] Black, F. (1987). *Business Cycles and Equilibrium*. New York, Basil Blackwell.

[16] Black, F. (2009). *Business Cycles and Equilibrium, Updated Edition*. Hoboken, New Jersey, John Wiley & Sons.

[17] Blundell, R. and Bond, S. (1998). Initial Conditions and Moment Restrictions in Dynamic Panel Data Models. *Journal of Econometrics* 87(1): 115-143.

[18] Blundell, R. and Bond, S. (2000). GMM Estimation with Persistent Panel Data: An Application to Production Functions. *Econometric Reviews* 19(3): 321-340.

[19] Bond, S. R. (2002). Dynamic Panel Data Models: A Guide to Micro Data Methods and Practice. *Portuguese Economic Journal* 1(2): 141-162.

[20] Brandt, L. and Zhu, X. (2000). Redistribution in a Decentralized Economy: Growth and Inflation in China under Reform. *Journal of Political Economy* 108(2): 422-439.

[21] Brandt, L. and Zhu, X. (2001). Soft Budget Constraint and Inflation Cycles: A Positive Model of the Macro-Dynamics in China during Transition. *Journal of Development Economics* 64(2): 437-457.

[22] Burnside, A. C. and Tabova, A. (2009). Risk, Volatility, and the Global Cross-Section of Growth Rates. *NBER Working Paper*.

[23] Caballero, R. J. (1991). On the Sign of the Investment-Uncertainty Relationship. *American Economic Review* 81(1): 279-288.

[24] Caballero, R. J., Engel, E. M. R. A. and Haltiwanger, J. C. (1995). Plant-Level Adjustment and Aggregate Investment Dynamics. *Brookings Papers on Economic Activity* 26(2): 1-54.

[25] Caballero, R. J. and Hammour, M. L. (1996). On the Timing and Efficiency of Creative Destruction. *Quarterly Journal of Economics* 111(3): 805-852.

[26] Candelon, B., Muysken, J. and Vermeulen, R. (2010). Fiscal Policy and Monetary Integration in Europe: An Update. *Oxford Economic Papers* 62(2): 323-349.

[27] Chen, Y. and Zhou, Y. (2006). Welfare Cost of China's Business Cycle. *Journal of World Economy (Chinese)* 2006(2): 11-19.

[28] Chong, A. and Gradstein, M. (2009). Volatility and Firm Growth. *Journal of Economic Growth* 14(1): 1-25.

[29] Dawson, J. W., Dejuan, J. P., J., S. J. and Stephenson, E. F. (2001). Economic Information versus Quality Variation in Cross-Country Data. *Canadian Journal of Economics* 34(4): 988-1009.

[30] Dawson, J. W. and Stephenson, E. F. (1997). The Link between Volatility and Growth: Evidence from the States. *Economics Letters* 55(3): 365-369.

[31] Dejuan, J. and Gurr, S. (2004). On the Link between Volatility and Growth: Evidence from Canadian Provinces. *Applied Economics Letters* 11(5): 279-282.

[32] Fatás, A. and Mihov, I. (2001). Government Size and Automatic Stabilizers: International and Intranational Evidence. *Journal of International Economics* 55(1): 3-28.

[33] Fatás, A. and Mihov, I. (2003). The Case for Restricting Fiscal Policy Discretion. *Quarterly Journal of Economics* 118(4): 1419-1447.

[34] Fatás, A. and Mihov, I. (2005). Policy Volatility, Institutions and Economic Growth. *CEPR Discussion Papers.*

[35] Gao, X. (2007). Business Cycle Accounting for the Chinese Economy. *MPRA Paper.*

[36] Gong, G. and Lin, J. Y. (2008). Deflationary Expansion: An Overshooting Perspective to the Recent Business Cycle in China. *China Economic Review* 19(1): 1-17.

[37] Hao, C. (2006). Development of Financial Intermediation and Economic Growth: The Chinese Experience. *China Economic Review* 17(4): 347-362.

[38] Hasan, I., Wachtel, P. and Zhou, M. (2009). Institutional Development, Financial Deepening and Economic Growth: Evidence from China. *Journal of Banking & Finance* 33(1): 157-170.

[39] He, Q., Chong, T.-L. T. and Shi, K. (2009). What Accounts for Chinese Business Cycle? *China Economic Review* 20(4): 650-661.

[40] Hess, G. D. and Shin, K. (1997). International and Intranational Business Cycles. *Oxford Review of Economic Policy* 13(3): 93-109.

[41] Hess, G. D. and Shin, K. (1998). Intranational Business Cycles in the United States. *Journal of International Economics* 44(2): 289-313.

[42] Hnatkovska, V. and Loayza, N. (2005). Volatility and Growth. *Managing Economic Volatility and Crises: A Practitioner's Guide.* Aizenman, J. and Pinto, B. Cambridge, Cambridge University Press.

[43] Ho, K. Y. and Tsui, A. K. C. (2004). Analysis of Real GDP Growth Rates of Greater China: An Asymmetric Conditional Volatility Approach. *China Economic Review* 15(4): 424-442.

[44] Hsu, M. and Zhao, M. (2009). China's Business Cycles Between 1954-2004: Productivity and Fiscal Policy Changes. *MPRA Paper.*

[45] Imbs, J. (2002). Why the Link between Volatility and Growth is both Positive and Negative. *CEPR Discussion Papers.*

[46] Imbs, J. (2007). Growth and Volatility. *Journal of Monetary Economics* 54(7): 1848-1862.

[47] Kose, M. A., Prasad, E. S. and Terrones, M. E. (2006). How Do Trade and Financial Integration Affect the Relationship between Growth and Volatility? *Journal of International Economics* 69(1): 176-202.

[48] Laurenceson, J. and Rodgers, D. (2010). China's Macroeconomic Volatility - How Important is the Business Cycle? *China Economic Review* 21(2): 324-333.

[49] Levine, R. and Renelt, D. (1992). A Sensitivity Analysis of Cross-Country Growth Regressions. *American Economic Review* 82(4): 942-963.

[50] Levine, R. and Zervos, S. (1996). Stock Market Development and Long-Run Growth. *World Bank Economic Review* 10(2): 323.

[51] Li, H. and Zhang, J. (2007). Do High Birth Rates Hamper Economic Growth? *Review of Economics and Statistics* 89(1): 110-117.

[52] Loayza, N. V., Rancie`re, R., Serve´n, L. and Ventura, J. (2007). Macroeconomic Volatility and Welfare in Developing Countries: An Introduction. *World Bank Economic Review* 21(3): 343-357.

[53] Lucas, R. E. (1987). *Models of Business Cycles.* New York, Basil Blackwell.

[54] Lucas, R. E. (2003). Macroeconomic Priorities. *American Economic Review* 93(1): 1-14.

[55] Martin, P. and Rogers, C. A. (2000). Long-term Growth and Short-term Economic Instability. *European Economic Review* 44(2): 359-381.

[56] Michael, B. (2004). Chinese Macroeconomic Stabilisation and Reform: A Briefing Note. *China and World Economy* 12(3): 61-69.

[57] Mirman, L. J. (1971). Uncertainty and Optimal Consumption Decisions. *Econometrica* 39(1): 179-185.

[58] Mobarak, A. M. (2005). Democracy, Volatility, and Economic Development. *Review of Economics and Statistics* 87(2): 348-361.

[59] Naughton, B. J. (1995a). China's Macroeconomy in Transition. *China Quarterly*(144): 1083-1104.

[60] Naughton, B. J. (1995b). *Growing Out of the Plan: Chinese Economic Reform, 1978-1993.* New York, Cambridge University Press.

[61] Oppers, S. E. (1997). Macroeconomic Cycles in China *IMF Working Paper.*

[62] Otrok, C. (2001). On Measuring the Welfare Cost of Business Cycles. *Journal of Monetary Economics* 47(1): 61-92.

[63] Pallage, S. and Robe, M. A. (2003). On the Welfare Cost of Economic Fluctuations in Developing Countries. *International Economic Review* 44(2): 677-698.

[64] Pindyck, R. S. (1991). Irreversibility, Uncertainty, and Investment. *Journal of Economic Literature* 29(3): 1110-1148.

[65] Qin, D. and Song, H. (2009). Sources of Investment Inefficiency: The Case of Fixed-Asset Investment in China. *Journal of Development Economics* 90(1): 94-105.

[66] Rafferty, M. (2005). The Effects of Expected and Unexpected Volatility on Long-Run Growth: Evidence from 18 Developed Economies. *Southern Economic Journal* 71(3): 582-591.

[67] Ramey, G. and Ramey, V. A. (1995). Cross-Country Evidence on the Link Between Volatility and Growth. *American Economic Review* 85(5): 1138-1151.

[68] Ranciere, R., Tornell, A. and Westermann, F. (2003). Crises and Growth: A Re-Evaluation. *NBER Working Paper*.

[69] Ranciere, R., Tornell, A. and Westermann, F. (2008). Systemic Crises and Growth. *Quarterly Journal of Economics* 123(1): 359-406.

[70] Ravallion, M. and Jalan, J. (1999). Are the Poor Less Well-insured? Evidence on Vulnerability to Income Risk in Rural China. *Journal of Development Economics* 58(1): 61-81.

[71] Tornell, A., Westermann, F. and Martinez, L. (2004). The Positive Link between Financial Liberalization, Growth and Crises. *NBER Working Paper*.

[72] Turnovsky, S. J. and Chattopadhyay, P. (2003). Volatility and Growth in Developing Economies: Some Numerical Results and Empirical Evidence. *Journal of International Economics* 59(2): 267-295.

[73] Windmeijer, F. (2005). A Finite Sample Correction for the Variance of Linear Efficient Two-Step GMM Estimators. *Journal of Econometrics* 126(1): 25-51.

[74] Xu, X. (2002). Have the Chinese Provinces Become Integrated Under Reform? *China Economic Review* 13(2-3): 116-133.

[75] Xu, X. and Voon, J. P. (2003). Regional Integration in China: A Statistical Model. *Economics Letters* 79(1): 35-42.

[76] Yang, D. T. (1999). Urban-Biased Policies and Rising Income Inequality in China. *The American Economic Review* 89(2): 306-310.

[77] Yang, D. T. (2002). What Has Caused Regional Inequality in China? *China Economic Review* 13(4): 331-334.

[78] Young, A. (1995). The Tyranny of Numbers: Confronting the Statistical Realities of the East Asian Growth Experience. *Quarterly Journal of Economics* 110(3): 641-680.

[79] Yu, Q. (1997). Economic Fluctuation, Macro Control, and Monetary Policy in the Transitional Chinese Economy. *Journal of Comparative Economics* 25(2): 180-195.

[80] Yusuf, S. (1994). China's Macroeconomic Performance and Management During Transition. *Journal of Economic Perspectives* 8(2): 71-92.

[81] Zhang, N. (2011a). Has the Chinese Economy Become Less Volatile? Structural Break Detection and Volatility Decomposition. *mimeo.* Department of Economics, Chinese University of Hong Kong.

[82] Zhang, N. (2011b). What Accounts for the Volatility of China's Economic Growth? *mimeo.* Department of Economics, Chinese University of Hong Kong.

Tables and Figures

Table 1: Mean of Average Growth and Volatility for Different Groups

	Full sample	Periods					
	1978-2008	1978-1982	1983-1987	1988-1992	1993-1997	1998-2002	2003-2008
Growth							
All	9.02	7.56	9.50	6.79	10.28	8.27	11.30
East	9.72	8.21	10.26	8.26	11.66	8.56	11.12
Center	8.70	7.02	9.17	5.44	10.21	8.22	11.55
West	8.56	7.31	8.97	6.29	8.95	8.01	11.29
Volatility							
All	3.88	4.99	4.01	4.62	2.22	1.07	1.33
East	4.21	5.28	4.00	5.97	3.12	1.10	1.41
Center	3.79	4.42	4.69	4.06	1.49	1.29	1.44
West	3.63	5.10	3.53	3.68	1.86	0.88	1.15

Note: All, East, Center and West represent all provinces, eastern province, central province and western provinces, respectively.

Table 2: Growth and Volatility with Group Dummies (Cross-section)

	(1) All	(2) East	(3) Center	(4) West	(5) Dummy
Volatility	0.587**	0.492	0.393	0.391	
	(0.204)	(0.467)	(0.259)	(0.422)	
Volatility*East					0.562*
					(0.241)
Volatility*Center					0.359
					(0.236)
Volatility*West					0.339
					(0.267)
Constant	6.744**	7.650**	7.206**	7.148**	7.342**
	(0.760)	(1.971)	(1.043)	(1.510)	(0.930)
Observations	30	11	8	11	30
Adjusted R-squared	0.171	0.019	0.160	0.004	0.259

Note: Dependent variable is average growth rate of GDP per capita over 1978-2008. All, East, Center and West represent all provinces, eastern province, central province and western provinces, respectively. Robust standard errors are reported in parentheses. **, *, and + indicate significance levels of 1%, 5%, and 10%, respectively.

Table 3: Growth and Volatility with Standard Controls (Cross-section)

	(1)	(2)	(3)	(4)
Volatility	0.587**	0.490*	0.468**	0.480*
	(0.204)	(0.214)	(0.158)	(0.220)
Initial GDPP		-1.011**	-1.396**	-0.919**
		(0.339)	(0.450)	(0.313)
Initial human capital		1.951+	0.742	0.572
		(1.017)	(1.334)	(1.546)
Investment rate			0.653	
			(1.261)	
Population growth			-1.938*	
			(0.923)	
Investment rate (I)				-0.406
				(0.605)
Population growth (I)				-0.652
				(0.515)
Constant	6.744**	11.20**	15.38**	15.07**
	(0.760)	(1.575)	(2.565)	(2.632)
Observations	30	30	30	30
Adjusted R-squared	0.171	0.213	0.329	0.233

Note: Dependent variable is average growth rate of GDP per capita over 1978-2008. Robust standard errors are reported in parentheses. **, *, and + indicate significance levels of 1%, 5%, and 10%, respectively.

Table 4: Growth and Volatility with Group Dummies (Panel)

	(1)	(2)	(3)	(4)	(5)
	All	East	Center	West	Dummy
Volatility	0.392**	0.305	0.196	0.295	
	(0.125)	(0.205)	(0.146)	(0.273)	
Volatility*East					0.452**
					(0.108)
Volatility*Center					0.169
					(0.127)
Volatility*West					0.207
					(0.156)
Constant	5.610**	6.596**	6.151**	5.807**	6.100**
	(0.691)	(1.463)	(0.795)	(1.204)	(0.689)
Observations	180	66	48	66	180
Adjusted R-squared	0.455	0.302	0.747	0.433	0.488

Note: Dependent variable is average growth rate of GDP per capita over each 5-year period. Robust standard errors are reported in parentheses. **, *, and + indicate significance levels of 1%, 5%, and 10%, respectively. All regressions include period dummies.

Table 5: Growth and Volatility with Standard Controls (Panel)

	(1)	(2)	(3)	(4)
Volatility	0.392**	0.392**	0.400**	0.389**
	(0.125)	(0.126)	(0.133)	(0.129)
Initial GDPP		-0.0481	-0.611+	-0.220
		(0.327)	(0.369)	(0.358)
Initial human capital		-0.247	-1.686	-1.866
		(1.177)	(1.293)	(1.340)
Investment rate			0.682	
			(0.786)	
Population growth			-2.153**	
			(0.513)	
Investment rate (I)				-0.546
				(0.715)
Population growth (I)				-1.372**
				(0.453)
Constant	5.610**	6.341**	13.10**	13.90**
	(0.691)	(1.791)	(3.206)	(3.103)
Observations	180	180	180	180
Adjusted R-squared	0.455	0.449	0.505	0.481

Note: Dependent variable is average growth rate of GDP per capita over each of 5-year period. Robust standard errors are reported in parentheses. **, *, and + indicate significance levels of 1%, 5%, and 10%, respectively. All regressions include period dummies.

Table 6: Dynamic Panel GMM Estimations

	Benchmark	One-Step		Two-Step		Revised	One-Step		Two-Step	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Lagged growth						0.144	0.102	0.118	-0.0554	0.0672
						(0.0885)	(0.0924)	(0.0860)	(0.115)	(0.100)
Volatility	0.400**	0.634**	0.638**	0.607+	0.799*	0.396**	0.545**	0.517**	0.539**	0.521**
	(0.133)	(0.146)	(0.115)	(0.308)	(0.316)	(0.142)	(0.119)	(0.105)	(0.169)	(0.169)
Initial GDPP	-0.611+	-0.585	-0.351	-0.597	-0.0231	-0.769+	-0.743	-0.419	0.185	-1.005
	(0.369)	(0.521)	(0.435)	(1.040)	(1.150)	(0.427)	(0.589)	(0.517)	(1.268)	(1.117)
Initial human capital	-1.686	-1.927	-1.705	-2.822	-3.086	-1.859	-2.217	-1.373	-4.839+	-1.005
	(1.293)	(1.558)	(1.606)	(2.989)	(3.393)	(1.395)	(1.654)	(1.480)	(2.810)	(3.998)
Investment rate	0.682	0.420		1.028		1.350	1.337		3.355+	
	(0.786)	(0.797)		(1.112)		(0.892)	(0.935)		(1.721)	
Population growth	-2.153**	-2.281**		-2.382*		-2.421**	-2.515**		-4.012**	
	(0.513)	(0.602)		(1.031)		(0.597)	(0.735)		(1.174)	
Investment rate (I)			-0.831		0.171			-0.212		-0.730
			(0.828)		(1.683)			(0.794)		(1.690)
Population growth (I)			-1.520**		-1.606			-1.665*		-2.356*
			(0.550)		(1.057)			(0.625)		(0.860)
Constant	13.10**	13.19**	14.53**	12.73	10.09	16.49**	17.24**	18.00**	8.452	25.40*
	(3.206)	(3.274)	(3.777)	(8.206)	(9.274)	(4.209)	(3.951)	(3.694)	(12.97)	(11.69)
Observations	180	180	180	180	180	150	150	150	150	150
Adjusted R-squared	0.505					0.565				
AR(1) Test		0.000	0.000	0.001	0.001		0.001	0.002	0.009	0.010
AR(2) Test		0.265	0.312	0.296	0.231		0.832	0.732	0.486	0.777
Hansen Test		1.000	1.000	1.000	1.000		1.000	1.000	1.000	1.000

Note: Dependent variable is average growth rate of GDP per capita over each of 5-year period. Robust standard errors are reported in parentheses. **, *, and + indicate significance levels of 1%, 5%, and 10%, respectively. All regressions include period dummies.

Table 7: Robustness Test with Alternative Regression Framework (Cross-section)

VARIABLES	(1) Benchmark	(2) W-GDP	(3) W-POP	(4) Quantile
Volatility	0.468**	0.496*	0.480**	0.468*
	(0.158)	(0.178)	(0.172)	(0.252)
Initial GDPP	-1.396**	-1.411**	-1.402**	-1.279
	(0.450)	(0.474)	(0.465)	(0.845)
Initial human capital	0.742	0.707	0.777	-0.0299
	(1.334)	(1.431)	(1.373)	(2.071)
Investment rate	0.653	0.722	0.748	0.580
	(1.261)	(1.305)	(1.273)	(1.846)
Population growth	-1.938*	-1.921+	-1.933+	-2.268**
	(0.923)	(0.979)	(0.948)	(1.083)
Constant	15.38**	15.19**	14.97**	16.12***
	(2.565)	(2.656)	(2.571)	(5.087)
Observations	30	30	30	30
Adjusted R-squared	0.329	0.308	0.303	-

Note: Dependent variable is average growth rate of GDP per capita over 1978-2008. Robust standard errors are reported in parentheses. **, *, and + indicate significance levels of 1%, 5%, and 10%, respectively.

Table 8: Robustness Test with Alternative Regression Framework (Panel)

VARIABLES	(1) Benchmark	(2) W-GDP	(3) W-POP	(4) Quantile	(5) Fixed Effect	(6) IV-2SLS
Volatility	0.400**	0.379**	0.378**	0.399***	0.210+	0.818*
	(0.133)	(0.122)	(0.127)	(0.0940)	(0.127)	(0.363)
Initial GDPP	-0.611+	-0.502	-0.488	-0.408	-3.676**	-0.698+
	(0.369)	(0.365)	(0.363)	(0.411)	(0.965)	(0.412)
Initial human capital	-1.686	-2.368+	-1.947	-2.201*	-3.505	-2.523*
	(1.293)	(1.226)	(1.259)	(1.244)	(2.256)	(1.268)
Investment rate	0.682	0.887	0.792	0.785	2.631*	1.069
	(0.786)	(0.782)	(0.785)	(0.707)	(1.321)	(0.857)
Population growth	-2.153**	-2.208**	-2.129**	-2.290***	-2.390**	-2.602**
	(0.513)	(0.485)	(0.501)	(0.475)	(0.675)	(0.555)
Constant	13.10**	12.91**	12.35**	12.56***	32.31**	19.04**
	(3.206)	(3.186)	(3.198)	(3.081)	(9.354)	(3.920)
Observations	180	180	180	180	180	150
Adjusted R-squared	0.505	0.527	0.511	-	0.646	0.520

Note: Dependent variable is average growth rate of GDP per capita over each of 5-year period. Robust standard errors are reported in parentheses. **, *, and + indicate significance levels of 1%, 5%, and 10%, respectively. All regressions include period dummies.

Table 9: Robustness Test with Additional Controls (Cross-section)

VARIABLES	(1) Benchmark	(2) GDP	(3) Population	(4) Government	(5) Primary	(6) Loan	(7) Non-SOE	(8) Trade	(9) All
Volatility	0.468**	0.643**	0.660**	0.476*	0.555**	0.453*	0.531**	0.207	0.489*
	(0.158)	(0.172)	(0.181)	(0.191)	(0.195)	(0.164)	(0.160)	(0.196)	(0.203)
Initial GDPP	-1.396**	-1.373**	-0.507	-1.401**	0.188	-1.454**	-0.811+	-2.315**	4.196
	(0.450)	(0.485)	(0.603)	(0.437)	(0.913)	(0.485)	(0.464)	(0.462)	(4.416)
Initial human capital	0.742	0.609	0.596	0.787	0.366	0.843	1.301	-0.0591	-0.489
	(1.334)	(1.265)	(1.291)	(1.345)	(1.278)	(1.462)	(1.121)	(1.013)	(1.142)
Investment rate	0.653	2.931*	2.777*	0.622	1.397	0.781	2.135+	0.952	2.608*
	(1.261)	(1.244)	(1.231)	(1.434)	(1.260)	(1.240)	(1.060)	(0.904)	(1.217)
Population growth	-1.938*	-0.898	-0.917	-1.961*	-2.364*	-2.016*	-0.803	-2.193**	-1.277+
	(0.923)	(0.881)	(0.880)	(0.875)	(0.922)	(0.860)	(0.652)	(0.615)	(0.664)
Additional Control	-	0.881**	0.837**	0.0627	1.451*	-0.0248	2.113**	0.724**	-
		(0.288)	(0.281)	(0.555)	(0.641)	(0.0668)	(0.570)	(0.224)	
Constant	15.38**	0.325	-6.797	15.31**	-2.723	15.36**	-3.796	21.57**	-48.90
	(2.565)	(5.683)	(7.873)	(2.582)	(7.684)	(2.727)	(6.019)	(3.613)	(38.44)
Observations	30	30	30	30	30	30	30	30	30
Adjusted R-squared	0.329	0.437	0.432	0.300	0.398	0.306	0.606	0.561	0.711

Note: Dependent variable is average growth rate of GDP per capita over 1978-2008. Robust standard errors are reported in parentheses. **, *, and + indicate significance levels of 1%, 5%, and 10%, respectively.

Table 10: Robustness Test with Additional Controls (Panel)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
VARIABLES	Benchmark	GDP	Population	Government	Primary	Loan	Non-SOE	Trade	FDI	All
Volatility	0.400**	0.399**	0.401**	0.355*	0.386**	0.397**	0.317*	0.283*	0.362**	0.209
	(0.133)	(0.145)	(0.145)	(0.137)	(0.123)	(0.135)	(0.146)	(0.130)	(0.121)	(0.131)
Initial GDPP	-0.611+	-0.915**	-0.172	-0.678+	1.073+	-0.652+	-0.507	-2.337**	-1.211**	-5.594
	(0.369)	(0.346)	(0.378)	(0.378)	(0.578)	(0.364)	(0.360)	(0.498)	(0.422)	(4.387)
Initial human capital	-1.686	-1.500	-1.551	-1.837	-1.957	-1.520	-0.954	-2.210+	-3.296**	-2.518*
	(1.293)	(1.224)	(1.226)	(1.229)	(1.202)	(1.334)	(1.198)	(1.164)	(1.249)	(1.119)
Investment rate	0.682	2.147*	2.080*	1.220	0.950	0.733	1.650*	1.467+	1.741*	4.360**
	(0.786)	(1.003)	(1.017)	(0.816)	(0.750)	(0.779)	(0.748)	(0.752)	(0.821)	(0.856)
Population growth	-2.153**	-1.540**	-1.567**	-1.951**	-2.484**	-2.192**	-1.670**	-3.012**	-2.781**	-2.412**
	(0.513)	(0.521)	(0.519)	(0.540)	(0.477)	(0.504)	(0.514)	(0.488)	(0.539)	(0.501)
Additional Control		0.730**	0.703**	-0.976	1.677**	-0.0251	1.174**	0.916**	0.511**	4.734
		(0.219)	(0.224)	(0.646)	(0.450)	(0.0472)	(0.321)	(0.206)	(0.153)	(4.230)
Constant	13.10**	5.021	-1.249	13.94**	-4.330	13.08**	4.589	24.29**	20.73**	39.15
	(3.206)	(4.145)	(5.777)	(3.167)	(6.577)	(3.208)	(3.375)	(4.025)	(3.746)	(39.07)
Observations	180	180	180	180	180	180	179	177	149	149
Adjusted R-squared	0.505	0.536	0.535	0.514	0.548	0.503	0.547	0.558	0.601	0.681

Note: Dependent variable is average growth rate of GDP per capita over each of 5-year period. Robust standard errors are reported in parentheses. **, *. and + indicate significance levels of 1%, 5%. and 10%, respectively. All regressions include period dummies.

Table 11: Growth and Volatility with Alternative Volatility Measure (Cross-section)

VARIABLES	(1) Benchmark	(2) CPI	(3) CPI	(4) CPI	(5) TFP	(6) TFP	(7) TFP
Volatility	0.468**	0.446	0.215	0.691+	0.178	0.221	0.232+
	(0.158)	(0.363)	(0.348)	(0.382)	(0.163)	(0.161)	(0.120)
Initial GDPP	-1.396**		-1.193**	-1.716**		-1.356**	-1.765**
	(0.450)		(0.334)	(0.513)		(0.371)	(0.478)
Initial human capital	0.742		2.066*	0.315		2.432*	1.168
	(1.334)		(0.949)	(1.232)		(1.003)	(1.245)
Investment rate	0.653			1.982			0.746
	(1.261)			(1.266)			(1.282)
Population growth	-1.938*			-2.645*			-2.046+
	(0.923)			(0.975)			(1.011)
Constant	15.38**	6.243*	12.87**	11.58*	8.383**	13.99**	18.05**
	(2.565)	(2.292)	(2.707)	(4.319)	(0.579)	(1.685)	(3.100)
Observations	30	30	30	30	30	30	30
Adjusted R-squared	0.329	0.011	0.078	0.282	-0.007	0.115	0.243

Note: Dependent variable is average growth rate of GDP per capita over 1978-2008. Robust standard errors are reported in parentheses. TFP and CPI indicate the volatility is measured as standard deviation of TFP growth and CPI, respectively. **, *, and + indicate significance levels of 1%, 5%, and 10%, respectively.

Table 12: Growth and Volatility with Alternative Volatility Measure (CPI, Panel)

VARIABLES	(1) Benchmark	(2) Benchmark -FE	(3) Benchmark -GMM	(4) CPI	(5) CPI	(6) CPI-FE	(7) CPI-GMM
Volatility	0.400**	0.210+	0.607+	0.433*	0.622**	0.392**	0.788**
	(0.133)	(0.127)	(0.308)	(0.173)	(0.175)	(0.145)	(0.237)
Initial GDPP	-0.611+	-3.676**	-0.597	0.202	-0.483	-3.058**	-0.291
	(0.369)	(0.965)	(1.040)	(0.360)	(0.370)	(1.010)	(0.664)
Initial human capital	-1.686	-3.505	-2.822	-0.905	-2.746*	-5.028*	-4.696
	(1.293)	(2.256)	(2.989)	(1.241)	(1.240)	(2.341)	(3.500)
Investment rate	0.682	2.631*	1.028		1.181	2.426+	1.194
	(0.786)	(1.321)	(1.112)		(0.892)	(1.424)	(1.265)
Population growth	-2.153**	-2.390**	-2.382*		-2.691**	-2.727**	-3.128**
	(0.513)	(0.675)	(1.031)		(0.542)	(0.679)	(0.916)
Constant	13.10**	32.31**	12.73	6.551**	13.42**	31.62**	15.36*
	(3.206)	(9.354)	(8.206)	(1.920)	(3.392)	(10.26)	(6.170)
Observations	180	180	180	180	180	180	180
Adjusted R-squared	0.505	0.646		0.428	0.514	0.656	
AR(1) Test			0.001				0.002
AR(2) Test			0.296				0.340
Hansen Test			1.000				1.000

Note: Dependent variable is average growth rate of GDP per capita over each of 5-year period. Robust standard errors are reported in parentheses. CPI indicates the volatility is measured as standard deviation of CPI. **, *, and + indicate significance levels of 1%, 5%, and 10%, respectively. All regressions include period dummies.

Table 13: Growth and Volatility with Alternative Volatility Measure (TFP, Panel)

VARIABLES	(1) Benchmark	(2) Benchmark -FE	(3) Benchmark -GMM	(4) TFP	(5) TFP	(6) TFP-FE	(7) TFP-GMM
Volatility	0.400**	0.210+	0.607+	0.391**	0.369**	0.312**	0.720*
	(0.133)	(0.127)	(0.308)	(0.117)	(0.120)	(0.106)	(0.287)
Initial GDPP	-0.611+	-3.676**	-0.597	-0.113	-0.651+	-3.710**	-0.664
	(0.369)	(0.965)	(1.040)	(0.342)	(0.388)	(0.903)	(0.708)
Initial human capital	-1.686	-3.505	-2.822	-0.172	-1.515	-3.171	-1.964
	(1.293)	(2.256)	(2.989)	(1.206)	(1.308)	(2.317)	(3.101)
Investment rate	0.682	2.631*	1.028		0.190	1.893	-1.083
	(0.786)	(1.321)	(1.112)		(0.869)	(1.342)	(1.508)
Population growth	-2.153**	-2.390**	-2.382*		-2.055**	-2.442**	-2.133*
	(0.513)	(0.675)	(1.031)		(0.577)	(0.677)	(0.877)
Constant	13.10**	32.31**	12.73	6.810**	14.97**	34.27**	18.39**
	(3.206)	(9.354)	(8.206)	(1.712)	(3.161)	(9.391)	(5.255)
Observations	180	180	180	177	177	177	177
Adjusted R-squared	0.505	0.646		0.454	0.500	0.669	
AR(1) Test			0.001				0.005
AR(2) Test			0.296				0.927
Hansen Test			1.000				1.000

Note: Dependent variable is average growth rate of GDP per capita over each of 5-year period. Robust standard errors are reported in parentheses. TFP indicates the volatility is measured as standard deviation of TFP growth. **, *, and + indicate significance levels of 1%, 5%, and 10%, respectively. All regressions include period dummies.

Table 14: Growth and Volatility with Alternative Sample Periods (2-Period)

VARIABLES	(1) Standard	(2) Standard	(3) Standard	(4) W-GDP	(5) W-POP	(6) Quantile	(7) Fixed Effect	(8) IV
Volatility	0.630**	0.623**	0.630**	0.646**	0.624**	0.792***	0.221	0.871+
	(0.194)	(0.193)	(0.195)	(0.187)	(0.192)	(0.194)	(0.305)	(0.453)
Initial GDPP		-1.012*	-0.646+	-0.965*	-0.952*	-1.498**	-4.332**	-1.336*
		(0.444)	(0.380)	(0.427)	(0.441)	(0.604)	(1.045)	(0.585)
Initial human capital		0.000339	-0.0591	-0.301	-0.0412	0.397	-0.565	-1.733
		(1.443)	(1.680)	(1.459)	(1.476)	(1.682)	(2.789)	(1.626)
Investment rate		0.220		0.337	0.315	0.887	3.847	1.056
		(1.204)		(1.155)	(1.203)	(1.304)	(2.327)	(1.285)
Population growth		-1.956*		-2.052**	-1.931*	-2.579***	-2.287+	-3.805**
		(0.740)		(0.729)	(0.743)	(0.770)	(1.211)	(0.758)
Investment rate (1)			-0.599					
			(0.762)					
Population growth (1)			-0.851+					
			(0.475)					
Constant	4.974**	13.86**	12.89**	13.64**	13.15**	14.32***	27.71*	20.80**
	(0.871)	(3.724)	(3.781)	(3.887)	(3.854)	(4.874)	(10.77)	(4.975)
Observations	60	60	60	60	60	60	60	30
Adjusted R-squared	0.465	0.531	0.490	0.543	0.529		0.728	0.543

Note: Dependent variable is average growth rate of GDP per capita over each of 15-year period. Robust standard errors are reported in parentheses. **, *, and + indicate significance levels of 1%, 5%, and 10%, respectively. All regressions include period dummies.

Table 15: Growth and Volatility with Alternative Sample Periods (3-Period)

VARIABLES	(1) Standard	(2) Standard	(3) Standard	(4) W-GDP	(5) W-POP	(6) Quantile	(7) Fixed Effect	(8) IV
Volatility	0.604**	0.578**	0.588**	0.604**	0.575**	0.524***	0.381**	0.743**
	(0.145)	(0.133)	(0.143)	(0.136)	(0.136)	(0.141)	(0.140)	(0.216)
Initial GDPP		-0.506	-0.0718	-0.409	-0.427	-0.570	-3.382**	-0.231
		(0.402)	(0.390)	(0.403)	(0.405)	(0.568)	(0.819)	(0.549)
Initial human capital		-1.393	-1.681	-1.812	-1.532	-2.185	-3.427	-2.505+
		(1.272)	(1.395)	(1.278)	(1.282)	(1.635)	(2.096)	(1.515)
Investment rate		-0.312		-0.207	-0.219	-0.395	0.787	-0.334
		(0.776)		(0.759)	(0.784)	(1.060)	(1.165)	(0.936)
Population growth		-1.762**		-1.741**	-1.748**	-1.978***	-1.757*	-1.882**
		(0.544)		(0.551)	(0.557)	(0.693)	(0.730)	(0.716)
Investment rate (I)			-1.082					
			(0.683)					
Population growth (I)			-0.771+					
			(0.452)					
Constant	5.712**	14.95**	13.79**	14.44**	14.30**	17.36***	35.60**	17.71**
	(0.712)	(2.791)	(2.714)	(2.915)	(2.935)	(4.311)	(6.968)	(3.754)
Observations	90	90	90	90	90	90	90	60
Adjusted R-squared	0.330	0.394	0.358	0.397	0.379		0.686	0.491

Note: Dependent variable is average growth rate of GDP per capita over each of 10-year period. Robust standard errors are reported in parentheses. **, *, and + indicate significance levels of 1%, 5%, and 10%, respectively. All regressions include period dummies.

Table 16. Volatility and Growth of Demand Components of GDP

	Investment		Consumption		Rural Consumption		Urban Consumption	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Component Volatility		-0.0113		0.128		0.178*		0.276**
		(0.111)		(0.120)		(0.0752)		(0.104)
Growth Volatility	0.222		-0.0938		-0.192		0.475**	
	(0.331)		(0.135)		(0.181)		(0.158)	
Initial GDPP	-0.554	-0.527	0.645	0.690	0.751	0.638	-0.802	-0.383
	(1.491)	(1.451)	(0.477)	(0.473)	(0.758)	(0.709)	(0.646)	(0.634)
Initial human capital	2.851	2.724	-2.427	-2.656+	-2.494	-1.958	0.0925	-0.578
	(4.738)	(4.760)	(1.580)	(1.580)	(2.106)	(2.126)	(2.079)	(2.117)
Investment rate	0.448	0.486	0.0381	-0.109	-1.276	-1.034	-1.121	-1.206
	(2.484)	(2.509)	(1.095)	(1.082)	(1.311)	(1.272)	(1.266)	(1.253)
Population growth	-1.561	-1.547	-1.369*	-1.423*	0.125	0.267	-1.180	-1.350
	(1.963)	(1.938)	(0.605)	(0.614)	(0.790)	(0.758)	(0.974)	(0.984)
Constant	9.286	10.49	11.14**	10.68*	14.78**	14.01**	16.79**	16.11*
	(13.13)	(12.80)	(4.062)	(4.330)	(5.111)	(4.829)	(5.639)	(6.496)
Observations	180	180	180	180	176	176	176	176
Adjusted R-squared	0.235	0.233	0.530	0.535	0.542	0.558	0.328	0.346

Note: Robust standard errors are reported in parentheses. **, *, and + indicate significance levels of 1%, 5%, and 10%, respectively. All regressions include period dummies.

Table 17 Volatility and Growth at Sectoral Level

	Cross-Section		2-Period		3-Period		6-Period	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Volatility	0.178**	0.108**	0.180**	0.135**	0.255**	0.226**	0.278**	0.270**
	(0.0472)	(0.0414)	(0.0442)	(0.0389)	(0.0394)	(0.0344)	(0.0440)	(0.0410)
Initial Value Added		-1.888**		-3.011**		-2.587**		-2.563**
		(0.405)		(0.451)		(0.397)		(0.440)
Initial Sector Share		-0.499		0.0197		0.181		-0.340
		(0.312)		(0.428)		(0.383)		(0.499)
Constant	4.118**	15.19**	3.831**	17.19**	4.157**	14.56**	3.140**	14.86**
	(0.402)	(1.868)	(0.454)	(1.812)	(0.423)	(1.486)	(0.493)	(1.590)
Period Fixed Effect	-	-	Yes	Yes	Yes	Yes	Yes	Yes
Province Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sector Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	360	340	713	681	1073	1023	1779	1706
Adjusted R squared	0.558	0.723	0.337	0.512	0.332	0.426	0.251	0.315

Note: Robust standard errors are reported in parentheses. **, *, and + indicate significance levels of 1%, 5%, and 10%, respectively.

Table 18: Volatility and Investment Share at Sectoral Level (Three Main Sectors)

	Cross-Section		2-Period		3-Period		6-Period	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Volatility	0.877	0.788	0.283	0.497	0.504+	0.613+	0.415*	0.424*
	(0.608)	(0.748)	(0.462)	(0.499)	(0.305)	(0.328)	(0.186)	(0.191)
Initial Value Added		2.135		0.974		1.204		1.275
		(2.497)		(1.830)		(1.469)		(1.186)
Initial Sector Share		-3.042		2.260		1.880		-0.199
		(3.547)		(2.799)		(2.142)		(1.764)
Secondary Dummy	24.71**	22.25**	24.94**	22.08**	23.95**	20.55**	25.22**	23.33**
	(1.942)	(4.249)	(1.651)	(2.734)	(1.342)	(2.662)	(1.150)	(2.034)
Tertiary Dummy	40.77**	38.82**	41.36**	40.76**	41.84**	40.51**	39.39**	38.47**
	(2.312)	(3.412)	(2.165)	(2.319)	(1.684)	(2.016)	(1.443)	(1.730)
Constant	3.901	3.083	4.826	-9.181	3.679	-9.352	2.856	-3.530
	(3.775)	(11.32)	(3.828)	(10.42)	(2.632)	(7.846)	(1.996)	(6.551)
Period Fixed Effect	-	-	Yes	Yes	Yes	Yes	Yes	Yes
Province Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	90	90	174	174	261	261	426	426
Adjusted R-squared	0.800	0.795	0.734	0.735	0.733	0.735	0.682	0.681

Note: Robust standard errors are reported in parentheses. **, *, and + indicate significance levels of 1%, 5%, and 10%, respectively.

Table 19: The Conduit for the Volatility-Growth Link

	Growth	GCF	GCF	TIFA	TIFA	Non-SOE	Non-SOE	FDI	FDI
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Volatility	0.400**	0.00325	0.000530	0.00911	0.00589	0.0674+	0.0711*	0.237**	0.192*
	(0.133)	(0.0148)	(0.0140)	(0.0131)	(0.0115)	(0.0368)	(0.0325)	(0.0758)	(0.0770)
Initial GDPP	-0.611+		0.197**		0.235**		-0.254*		1.129**
	(0.369)		(0.0490)		(0.0603)		(0.107)		(0.211)
Initial human capital	-1.686		-0.345*		-0.259		-0.339		0.846
	(1.293)		(0.145)		(0.186)		(0.347)		(1.002)
Investment rate	0.682								
	(0.786)								
Population growth	-2.153**		0.121*		0.203**		-0.513**		0.194
	(0.513)		(0.0560)		(0.0641)		(0.162)		(0.376)
Constant	13.10**	3.384**	2.386**	2.899**	1.390**	2.309**	5.309**	-1.955**	-12.64**
	(3.206)	(0.0810)	(0.328)	(0.0900)	(0.353)	(0.274)	(0.845)	(0.433)	(1.804)
Observations	180	180	180	180	180	179	179	149	149
Adjusted R-squared	0.505	0.401	0.468	0.613	0.666	0.442	0.494	0.503	0.652

Note: Robust standard errors are reported in parentheses. **, *, and + indicate significance levels of 1%, 5%, and 10%, respectively. All regressions include period dummies.

Table 20: Link between Growth and Different Volatility Components

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
	OLS	GMM	GMM-F	GMM-I	OLS-E	GMM-E	OLS	GMM	OLS	GMM	GMM-E	GMM-E	GMM-E
Volatility	0.391**	0.509*	0.103	0.142+	0.752**	0.620+					0.908**	0.740*	0.773*
	(0.128)	(0.221)	(0.0665)	(0.0774)	(0.168)	(0.276)					(0.324)	(0.298)	(0.334)
Fiscal Policy Volatility							-0.0423+	-0.139*			-0.0410		-0.0126
							(0.0251)	(0.0547)			(0.0399)		(0.109)
Investment Policy Volatility									-0.0237-	-0.0589-		-0.0347	0.0307
									(0.0143)	(0.0293)		(0.0422)	(0.0487)
Initial GDPP	-0.242	-1.039+	-0.700	-0.528	-0.475	-0.855	-0.110	-0.0423	-0.122	-0.527	-0.638	-0.842	-2.458
	(0.398)	(0.583)	(0.712)	(0.917)	(0.384)	(0.657)	(0.438)	(0.816)	(0.448)	(0.499)	(0.698)	(0.733)	(1.454)
Initial human capital	-1.817	-1.926	-2.031	-1.528	-1.481	-2.535	-2.184	-1.233	-2.413+	-2.905-	-2.365	-2.904	1.995
	(1.337)	(1.979)	(1.982)	(3.521)	(1.292)	(1.834)	(1.376)	(1.332)	(1.398)	(1.505)	(1.877)	(3.311)	(3.199)
Initial investment rate	-0.512	0.536	0.0639	0.0854	-0.655	0.205	-0.623	-1.459	-0.700	-0.686	-0.686	-0.394	-0.192
	(0.758)	(0.838)	(1.047)	(1.078)	(0.734)	(0.830)	(0.828)	(1.044)	(0.846)	(0.654)	(0.854)	(1.311)	(2.121)
Initial population growth	-1.390*	-2.192**	-2.215**	-2.038*	-1.369*	-2.253**	-1.289*	-0.791	-1.343*	-1.671*	-1.605-	-2.169-	-2.125
	(0.540)	(0.688)	(0.658)	(0.941)	(0.546)	(0.637)	(0.562)	(0.865)	(0.558)	(0.685)	(0.877)	(1.211)	(1.827)
Constant	13.86**	16.52**	17.09**	13.31*	15.78**	18.48**	16.34**	17.42**	17.00**	21.67**	19.04**	21.34-	25.14*
	(3.243)	(4.073)	(2.817)	(5.125)	(3.113)	(3.764)	(3.195)	(5.888)	(3.159)	(6.146)	(5.430)	(11.71)	(11.92)
Observations	174	174	174	174	174	174	174	174	174	174	174	174	174
Adjusted R-squared	0.477				0.526		0.431		0.429				
AR(1) Test		0.0007	0.0147	0.00550		0.0112		0.00118		0.00243	0.0207	0.0124	0.0330
AR(2) Test		0.506	0.930	0.764		0.350		0.639		0.486	0.377	0.329	0.887
Hansen Test		0.350	0.295	0.154		0.242		0.571		0.781	0.946	0.769	1.000

Note: Dependent variable is average growth rate of GDP per capita over each of 5-year period. Robust standard errors are reported in parentheses. **, *, and - indicate significance levels of 1%, 5%, and 10%, respectively. All regressions include period dummies. In specifications GMM-F and GMM-I, the volatility represents government expenditure volatility and investment volatility, respectively. In specifications OLS-P and GMM-P, the volatility represents expected volatility.

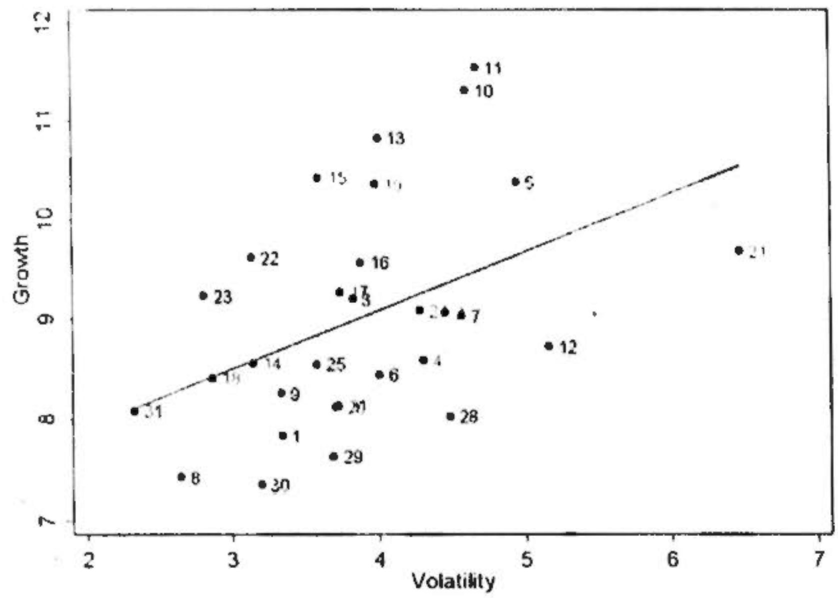

Figure 1: Growth and Volatility (Cross-Sectional)
Note: Growth and Volatility represent the mean and standard deviation of GDP per capita growth for Chinese provinces over the period 1978-2008, respectively.

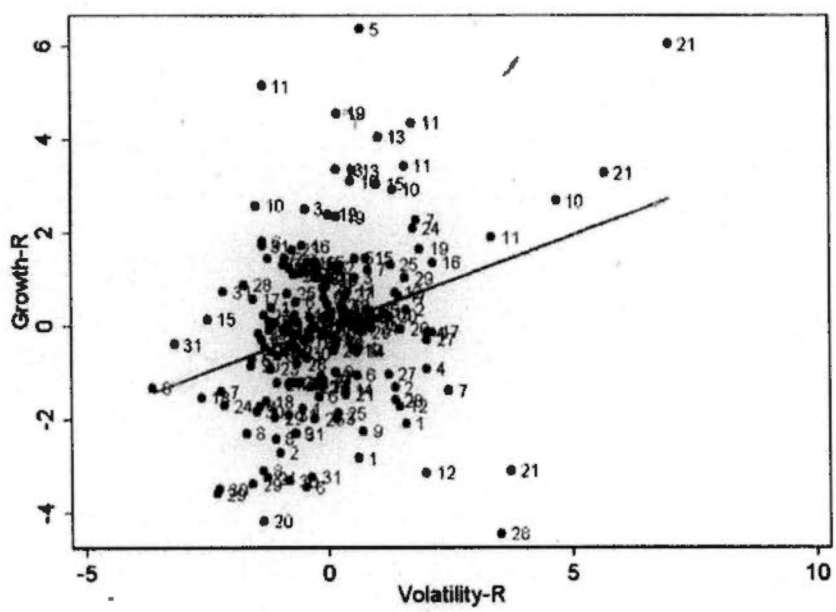

Figure 2: Growth and Volatility (Panel, with Period Dummies)
Note: Growth-R and Volatility-R represent the mean and standard deviation of GDP per capita growth for Chinese provinces over six 5-year intervals after controlling the effects of period dummies, respectively. The six intervals are 1978-1982, 1983-1987, 1988-1992, 1993-1997, 1998-2002, and 2003-2008.