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Growth-Cycle Nexus

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Abstract

This research sheds light on the negative correlation between economic growth and business cycle in less developed economies. Whereas many previous studies explain the negative correlation from a viewpoint in which business cycle affects economic growth, we attempt to present a hypothesis based on the other influence direction in which economic growth affects business cycle. We investigate the validity of the hypothesis using two methods: econometric analysis and numerical analysis. We find that the econometric analysis supports our hypothesis. The numerical analysis shows that the effect of the proposed hypothesis produces the negative correlation between economic growth and business cycle.

Keywords: Growth; Business Cycle; Less Developed Economies

JEL classification: E32, O40

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Growth-Cycle Nexus

1. Introduction

This research sheds light on why economic growth and business cycle in less developed economies are negatively correlated. It is well known that when we look at cross-country data, a country's business cycle in a period is small (large) if the country experiences a high (low) average economic growth rate in the period. We naturally wonder how this negative correlation between economic growth and business cycle is produced. For an explanation of this negative correlation mechanism, we present a hypothesis that specifically focuses on less developed economies.¹ We then examine the validity of the hypothesis using two different methods – econometrics and the Dynamic General Equilibrium (DGE) model. Economic growth and business cycle both have a strong influence on social welfare. It is socially significant to deepen our understanding of economic growth and business cycle.

Economic growth and business cycle by themselves are among the most important subjects in macroeconomics. Whereas these two research subjects are both important, they have been examined separately. In contrast, Ramey and Ramey (1995) find that

¹ Whereas our hypothesis focuses on developing countries, we do not intend to imply that a negative correlation in the developed country data does not exist.

economic growth rate and business cycle are negatively correlated in cross-country data.² The fact that two highly important macroeconomic phenomena relate to each other has attracted the interest of many scholars. Martin and Rogers (2000), Turnovsky and Chattopadhyay (2003), Hnatkovska and Loayza (2004), Imbs (2007), Loayza et al. (2007), Badinger (2010), Lee (2010), and many others have examined this relationship.

What we present in this paper is threefold: 1) our hypothesis on the negative correlation between economic growth and business cycle, 2) empirical evidence regarding the hypothesis, and 3) numerical evidence. The most salient feature of this research is our hypothesis. Previous research has examined this negative correlation by employing various arguments. Many of these studies are based on a view that business cycle affects economic growth; business cycle affects short-term economic variables, such as investment or labor.³ Changes in short-term economic variables affect long-term economic elements, such as physical capital or human capital, and the long-term elements eventually affect economic growth. In contrast, whereas previous research has

² To be precise, Ramey and Ramey (1995) find a weaker negative correlation in cross-country data from 92 countries, and they also find a relatively stronger negative correlation in cross-country data from 24 OECD countries.

Hnatkovska and Loayza (2004) find a negative correlation in an econometric analysis that specifically focuses on low-income countries.

³ Whereas there are many studies that examine this influence mechanism, not all of those previous studies support the mechanism.

examined a direction of influence in which business cycle affects economic growth, this research suggests an influence in the other direction in which economic growth affects business cycle. Our hypothesis based on this view is different from previous research. Nevertheless, this research does not necessarily deny the previously proposed hypotheses. It is very likely that both our hypothesis and the previous hypotheses individually account for different parts of the negative correlation.

The structure of the article is as follows. In Section 2, we first present our negative-correlation hypothesis. Second, we analyze the validity of the hypothesis using econometric methods. In Section 3, we numerically examine the validity of the hypothesis utilizing a DGE model. Section 4 provides the conclusions of our research.

2. Econometric analysis

As discussed in the Introduction, it is well known that economic growth rate and business cycle are negatively correlated. In this section, we present our hypothesis on how the negative correlation between economic growth rate and business cycle is produced, specifically focusing our research target on less developed economies. We then examine the validity of the hypothesis using econometric methods.

2.1. Hypothesis

In this subsection, we present our hypothesis on the mechanism producing a negative correlation between economic growth rate and business cycle. We explain the negative correlation by referring to two types of links; 1) a negatively correlated link of per capita GDP level – business cycle, and 2) a positively correlated link of economic growth rate – per capita GDP level. If these two links exist, we also expect the following link: economic growth rate – per capita GDP level – business cycle. This link produces the negative correlation between economic growth rate and business cycle.

The positively correlated link between per capita GDP level and business cycle is produced as follows. In general, as a developing country develops, it begins to produce more diverse industries. It is frequently observed that a developing country mainly produces primary goods and textiles in the early stage of economic development. After economic development, the country normally produces more diverse manufacturing goods, such as textiles, steel, electrical appliances, chemical products, and so forth. As a result of the diversification of production, the developing country can export a greater variety of goods than before.

If the developing country exports more diverse goods, its terms of trade (TOT) become more stable because of the following mechanisms. Export prices (i.e., the price index of

the aggregate export) are a weighted average of individual prices of a country's various export goods. Even if the individual prices of the country's export goods change unstably in the world market, if we calculate export prices (i.e., a weighted average) from prices of many different export goods, the export prices become stable, which eventually stabilizes TOT. In contrast, if we calculate export prices from only a few export goods, the export prices and TOT remain unstable. Accordingly, export-good-variety expansion stabilizes the TOT.

From these arguments, we expect a relationship between development levels and TOT volatilities. If we consider per capita GDP to be an index of economic development, we can express the relationship as follows: in accordance with the per capita GDP growth in a developing country, the developing country's variety of export goods increases, and this variety expansion reduces TOT volatility.

This statement is summarized in Assumption 1.

Assumption 1 As a developing country's per capita GDP grows, the country's TOT become less volatile.

Mendoza (1995) and Kose (2002) show that TOT fluctuation strongly affects a

developing country's business cycle.⁴ This fact and Assumption 1 imply that a country's per capita GDP growth stabilizes the country's business cycle. From these arguments, we expect a negatively correlated link between per capita GDP level and business cycle

Next, let us turn to explanations for a positively correlated link between economic growth rate (per capita GDP growth rate) and per capita GDP level. There are two rationales that support this positive correlation.

First, there is a straightforward mechanism producing a positive correlation between average per capita GDP growth rates and average per capita GDP levels: if average per capita GDP growth rates for a specific period are high, then the high average per capita GDP growth rates cause average per capita GDP levels of the same period to be high.

Second, previous studies on "absolute convergence" indirectly support our expectation of a positive correlation between the per capita GDP growth rate and the per capita GDP level.⁵ Absolute convergence is the relationship between the average per capita GDP growth rate of a period and the initial per capita GDP of that period. If there is a

⁴ To be precise, Kose (2002) introduces two import goods and their prices, instead of TOT, to the model.

⁵ "Conditional convergence" is another well-known concept on convergence. The concept's using variable is based on the idea of steady state. Because the concept's focus is very different from our interest, we do not mention this concept.

negative correlation between the average per capita GDP growth rate and the initial per capita GDP, the income difference between a lower initial per capita GDP country and a higher initial per capita GDP country converges. Note that the absolute convergence focuses on a relationship between average per capita GDP growth rates of a period and initial per capita GDPs of the same period, whereas in this study, we focus on the relationship between average per capita GDP growth rates of a period and the average per capita GDP levels of that period. In the case of the absolute convergence, even if the per capita GDP growth rate of a period is high, the initial per capita GDP is not affected by the high growth rate. In contrast, in the case of our focusing relationship between average per capita GDP growth rates and the average per capita GDP levels, a high average per capita GDP growth rate of a period directly raises the average per capita GDP level of the same period. Hence, the absolute convergence and our focusing relationship are different relationships. Meanwhile, previous studies on absolute convergence indirectly support our expectation of the positive correlation between the average per capita GDP growth rates of the period and the average per capita GDP levels. When we examine cross-country data, if there is a negative correlation between per capita GDP growth rates of a period and initial per capita GDPs of the period, then this negative correlation can become a factor that produces a negative correlation

between average per capita GDP growth rates and average per capita GDP levels of the period. This negative correlation might cancel out the positive correlation (which is explained above) between the average GDP growth rate and the average GDP level. Nonetheless, previous studies on absolute convergence suggest that there is no correlation between countries' per capita GDP growth rates and countries' initial per capita GDPs (see, for example, Barro and Sala-i-Martin, 2003). In other words, the previous studies on absolute convergence imply that the positive correlation between the average per capita GDP growth rate and the average per capita GDP level are not reduced by absolute convergence because absolute convergence does not hold.

Based on these two facts, in the cross-country data, we expect a positively correlated link between countries' average per capita GDP growth rates of a period and countries' average per capita GDP levels of the same period.

In this section, we first explained a mechanism that produces a negative correlation between the per capita GDP level and business cycle. And the negative correlation is produced by the following link: high (low) GDP level – large (small) variety of export goods – low (high) TOT volatility – low (high) business cycle. Second, we introduced a mechanism that produces a positively correlated link between the economic growth rate (per capita GDP growth rate) and the per capita GDP level. In this research, we propose

a hypothesis that these two links produce a negative correlation between economic growth rate and business cycle. This hypothesis accounts for the negative correlation introduced by Ramey and Ramey (1995). In Subsection 2.2, we will investigate the empirical validity of each of the above correlations.

2.2. Econometric results

In Subsection 2.1, we introduced several relationships between economic variables in proposing our negative correlation hypothesis. In this subsection, we empirically investigate the relationships using cross-country data. The data that are employed in this section are summarized in Appendix A.

Table 1 shows our estimation results. The number of observations depends on data availability.

Table 1

The first column displays a relationship between average per capita GDP growth rates (Growth) and standard deviations of the per capita GDP growth rates (GDP SD).

Following Ramey and Ramey (1995) and others, we regard the standard deviations of the economic growth rates as an index of business cycle. As shown in previous studies, the ordinary least squares coefficient (-0.60) is negative and significant. Our hypothesis

presumes that economic growth affects business cycle. To examine the existence of this influence direction, we employ a two-stage least squares analysis. In reference to instrument variables for economic growth rates, we adopt geographical data and regional dummy variables which are used in the growth regression literature.⁶ The results of the two-stage least squares analyses are shown in the second column of Table 1. The result does not change considerably; the coefficient (-0.63) is negative and significant. This result suggests that high economic growth rates reduce business cycle. This fact matches our hypothesis.

The third column of Table 1 corresponds to the relationship between per capita GDP and export good variety (EX Variety). “EX Variety” denotes an index of export good variety which we created. This index is a type of Gini coefficient that expresses how evenly a country’s export is distributed across export items whereas the conventional Gini coefficient expresses how evenly a country’s income is distributed across people. The conventional Gini coefficient becomes small if the income is evenly distributed across the people. Meanwhile, we adjusted “EX Variety” so that it becomes large if the export is evenly distributed across the export items. Hence, if this index of a country is large, it

⁶ We adopt regional dummy variables and an index of geography as instrument variables. For a detailed explanation of these variables, see Appendix A.

implies that the country has a variety of export goods whose individual share of the total exports is not small compared with the largest export good's share. The detailed procedure of how this index was created is given in Appendix A. When we explained our hypothesis, we expected that the export good variety would increase in accordance with economic growth because economic growth diversifies the domestic industry and the industrial diversification enables the country to export various types of export goods. The estimated parameter in the third column (5.29×10^{-6}) is positive and significant, and it supports our expectation.

The fourth column examines the relationship between export good variety and TOT volatility (TOT SD). In Subsection 2.1, we conjectured that this correlation was negative for the following reasons. Export prices (i.e., the price index of the aggregate export) are a weighted average of prices of various individual export goods. If the prices of the individual export goods are determined in the world market and if they behave as exogenous variables to a developing country, an increase of export goods variety stabilizes the export prices (i.e., the price index of the aggregate export) which are the weighted average of prices of various export goods. If the export prices become more stable, the volatility in TOT becomes smaller. In short, an increase of the export goods variety reduces the volatility in TOT. The estimated parameter in the fourth column

(-0.29) is negative and significant, which is consistent with our expectation.

The fifth column investigates the relationship between TOT volatility and GDP volatility (GDP SD). Based on a DGE model, Mendoza (1995) and Kose (2002) state that the fluctuations in the TOT strongly affect the fluctuations in the GDP. We employ this statement as a part of our hypothesis. The positive and significant coefficient in the fifth column (0.18) confirms this statement.

These results in the third, fourth, and fifth columns support our hypothesis on the link of high (low) average per capita GDP level – low (high) TOT volatility – low (high) business cycle.

Next, let us examine the correlation between average per capita GDP growth rate and average per capita GDP level. The first column of Table 2 shows the regression results pertaining to the relationship between average per capita GDP growth rates during the period from 1966 to 2005 and initial per capita GDPs (Ini GDP), which is per capita GDPs in 1966, based on cross-country data.

Table 2

This relationship corresponds to absolute convergence. The results suggest that there is no significant correlation between the two variables. This result is consistent with the previous studies on absolute convergence. The second column of the table shows the

relationship between average per capita GDP growth rates from 1966 to 2005 and average per capita GDP levels for the same period. These two variables are significantly positively correlated. These two results support our expectation of a positive correlation between per capita GDP growth rates and per capita GDP levels, as explained in Subsection 2.1.

All of the signs of the estimated coefficients in the relationships in Table 1 and Table 2 match our expectations which were explained in Subsection 2.1, and all of the coefficients are significant. These empirical facts support our hypothesis in Subsection 2.1.

3. Numerical Analysis

In Subsection 2.1, we explained our hypothesis of the negative correlation between economic growth and business cycle, explaining each relationship between the variables.

In Subsection 2.2, we found that the actual data support our conjectures on correlations that were assumed in our hypothesis. In these preceding sections, we examined the negative correlation between economic growth and business cycle without assuming a specific economic model. Then, we question whether an economic model reflecting the hypothesis in Subsection 2.1 actually produces a negative correlation between economic

growth rate and business cycle. We examine this question in this section. More specifically, we introduce Assumption 1, which is a key assumption of our hypothesis, to a standard DGE model. We then investigate whether the model produces a negative correlation.

3.1. Revised Assumption 1

Before constructing a DGE model with Assumption 1, we are required to revise Assumption 1 to introduce this assumption into our DGE model. If we only assume that the TOT volatility linearly decreases corresponding to the increase in per capita GDP, TOT volatility will become negative when per capita GDP becomes significantly large. However, the negative volatility is impossible. Furthermore, if the variety of export goods increases sufficiently, the further reduction of TOT volatility based on the increase of the export good variety (which is caused by an increase of per capita GDP) will be very limited. In fact, the data support this tendency. If we plot a scatter diagram of the relationship between per capita GDP level and TOT volatility, we find that there are two groups in the diagram; a group whose per capita GDP is lower than \$5525 and a group whose per capita GDP is higher than \$5525 (see Appendix B). In the scatter diagram, the lower per capita GDP group appears to have a negative correlation

between the per capita GDP and TOT volatility. Meanwhile, the higher per capita GDP group seems to have no correlation, and this higher per capita GDP group's average TOT volatility is approximately equal to the lowest value of the lower per capita GDP group's TOT volatility.

Table 3 statistically confirms this view on the correlations' significances.

Table 3

We regress TOT volatility on the per capita GDP. The first column shows the results of the lower per capita GDP group. The coefficient is significantly negative. The second column shows the results of the higher per capita GDP group. The results indicate that there is no correlation between the per capita GDP and TOT volatility, and TOT volatility does not decrease in this region even if the per capita GDP increases.

Based on these arguments and empirical results, in our DGE model, we adopt a revised version of Assumption 1.

Revised Assumption 1 The following relationships exist between per capita GDP and TOT volatility: 1) TOT volatility decreases in accordance with per capita GDP growth until the per capita GDP reaches a threshold; 2) after the per capita GDP reaches the threshold, the per capita GDP's growth does not strongly affect the reduction of TOT

volatility.

3.2. Model

In this subsection, we introduce a developing country DGE model. We presume two different types of goods: domestically produced goods (hereafter, domestic goods) and imported goods. We use a superscript M to express the imported goods.

We assume a representative agent who lives infinitely in a developing country. According to Kose (2002), in less developed economies, most of consumption is composed of domestic goods. Based on this fact, Kose posits that, in the building of a DGE model, a developing country consumes only domestic goods. In line with Kose, we also adopt this assumption. Employing the constant relative risk aversion instantaneous utility (u), we express the expected lifetime utility of the agent (U) as follows.

$$U = E_0 \left[\sum_{t=0}^{\infty} \beta^t u_t \right] \quad (1)$$

$$u_t = \frac{C_t^{1-\gamma} - 1}{1-\gamma} \quad (2)$$

β and γ represent a discount factor and a relative risk aversion parameter, respectively. C denotes domestic goods consumption. The agent faces a budget constraint of

$$y_t + P_t \cdot (1+r)B_{t-1} = C_t + I_t^D + P_t \cdot I_t^M + P_t \cdot B_t + \frac{\psi}{2} \left(\frac{B_t - \bar{B}}{y_t} \right)^2, \quad (3)$$

where y stands for income that corresponds to the GDP of the country. I^D expresses the amount of domestic goods spent for investment. I^M expresses the amount of imported goods spent for investment. P is the relative price of the imported goods to the domestic goods and is equal to $1/\text{TOT}$. Our target countries are small open economies, and they behave as price takers in the world market. Therefore, we consider P to be an exogenous shock variable. Its stochastic process is given later. B denotes the amount of international bond that is possessed by the representative agent. r is the interest rate of the bond. In line with Schmitt-Grohe and Uribe (2003) and many others, we introduce an adjustment cost of B , which is expressed as the last term of (3). \bar{B} in the adjustment cost represents a steady state value of B .

Next, let us turn to the production side of the economy. In our analysis, P plays an important role in the production sector. P affects two types of imported production factors: imported investment goods and imported intermediate goods. Considering P 's effect on the production factors, we employ a production process with three input factors: capital (K), labor (L), and imported intermediate goods (m^M). As shown in the calibration in Subsection 3.3, it is common that a developing country uses imported intermediate goods that are not produced in the country. For example, an agricultural

sector in a developing country normally uses imported chemical fertilizers that are not produced domestically. Another example is oil. Non-oil-producing less developed economies import oil for the production of goods. Meanwhile, we do not explicitly express domestic intermediate goods, which are produced in the domestic production sector, in this model. A part of the domestic goods is put back into the domestic production sector as intermediate goods, but we do not observe it unless the domestically produced intermediate good is sent out to another sector.

We assume that the imported intermediate goods (which include raw materials) are required for production and that they are not substitutable with capital and labor. We then adopt a production function in which imported intermediate goods and other inputs (capital and labor) are complementary.

$$Y_t = \min \left[\frac{A_t K_t^\alpha L_t^{1-\alpha}}{1-\phi}, \frac{m_t^M}{\phi} \right] \quad (4)$$

Note that the output (Y) in this model is different from the GDP. We treat output and GDP separately, and their relationship is represented by the standard definition: GDP (value-added) is equal to the output value less the intermediate goods value.

A denotes the productivity level, and we consider it to be an exogenous stochastic shock.

The shock process is explained later in this section. Labor is supplied by the agent, and

the maximum amount that the agent can supply at period t is denoted as \bar{L} .

$$L_t \leq \bar{L} \quad (5)$$

The capital's law of motion is given as

$$K_{t+1} = (1 - \delta)K_t + \tilde{I}_t - \frac{\eta}{2} \left(\frac{K_{t+1}}{K_t} - 1 \right)^2. \quad (6)$$

The last term of (6) expresses the adjustment cost of investment. \tilde{I} stands for a composite investment that is composed of a domestic and an imported investment.

In reference to the relationship between the domestic and imported capital goods, we consider that they have different roles in production. In the case of capital goods in less developed economies, simple capital goods are domestically produced, but complicated capital goods are imported (Bruton, 1998). In other words, in less developed economies, the domestic capital goods and the imported capital goods are different types of capital goods. According to Mody and Yilmaz (2002), substitutions between domestic capital goods and imported capital goods are low. From these facts, we presume that the relationship between domestic and imported capital goods is complementary. We then adopt the following function for making the composite investments.

$$\tilde{I}_t = \min \left[\frac{I_t^D}{\theta}, \frac{I_t^M}{1 - \theta} \right] \quad (7)$$

Let us now move on to market clearing conditions.

$$Y_t = C_t + I_t^D + X_t \quad (8)$$

X represents the export of domestic goods. Domestically produced goods are utilized as consumption, investment, or export.

By rewriting (8), we can derive the GDP's expenditure identity.

$$y_t = C_t + I_t + X_t - M_t, \quad (9)$$

where $y_t = Y_t - P_t m_t^M$, $I_t = I_t^D + P_t I_t^M$, $M_t = P_t(I_t^M + m_t^M)$.

y represents GDP, and the definition of GDP is based on the standard definition: the GDP (value-added) is equal to the output value less the intermediate goods value.

We assume that A and P follow the subsequent stochastic processes.

$$\ln A_t \sim N(\ln \bar{A}, \sigma_A^2) \quad (10)$$

$$\ln P_t \sim N(\ln \bar{P}, \sigma_P^2) \quad (11)$$

Finally, we introduce an assumption that characterizes this research. In this research, we attempt to explain why economic growth rates and business cycles are negatively correlated. To explain the negative-correlation phenomenon, we proposed a hypothesis in Subsection 2.1. We summarized a part of the hypothesis as Revised Assumption 1, and we confirmed the assumption's empirical validity in Subsection 3.1. The model introduced above, which is composed of Eqs. (1) to (11), is a standard DGE model.⁷ We now add Revised Assumption 1 to the standard model.

⁷ (8) and (9) are basically the same. We utilized only one of them.

$$\sigma_P = \begin{cases} \text{if } \bar{y}_t < y^*, & \tau_1 - \tau_2 \cdot \bar{y}_t \\ \text{otherwise,} & \sigma_P^* \end{cases} \quad (12)$$

where $\bar{y}_t = E_{t-1}(y_t | A_t = \bar{A}, P_t = \bar{P})$, $\tau_1 > 0, \tau_2 > 0$

Note that by assuming the population of our model economy is unity, the country's GDP and per capita GDP become identical. The first row of (12) states that as a developing country's per capita GDP grows, the country's P becomes less volatile. \bar{y} in (12) reflects the following notion: according to the discussion in Subsection 2.1, a degree of economic development affects TOT's (and eventually P 's) volatility. We here assume that the degree of economic development is not affected by a temporary productivity shock or a temporary TOT shock.⁸ We then consider \bar{y}_t , which is a potential per capita GDP independent of influences of the temporary shocks at a period t , to be the degree of economic development at the period t . Let us now turn to the explanation of the second row of (12). The second row expresses the lower limit of P 's volatility; once a developing country has grown well, P 's volatility ceases to decrease, even if the country's per capita GDP keeps growing.

In the following subsection, we examine whether Eq. (12), which represents the essence of our hypothesis in Subsection 2.1, successfully produces a negative correlation between economic growth rates and business cycles.

⁸ In the regressions in Table 3, we utilized per capita GDP averaged across periods, as the degree of economic development. In this case, by taking the average across periods, influence of temporary shocks are eliminated.

The representative agent maximizes its expected lifetime utility (1) subject to the constraints above. We solve the maximization problem using the value function iteration.

3.3. Calibration

In this subsection, we explain the parameter values that are employed in our simulation.

We set the annual discount factor β to 0.96, considering that values between 0.95 and 0.98 are commonly used in developing country DGE research. r is determined based on the following equation: $\beta(1+r) = 1$. With respect to γ , referring to the empirical research on less developed economies by Ostry and Reinhart (1992), we choose 2.61 as the value. \bar{B} is set to zero, which presumes that the long-run average bond (or debt) holding is zero. ψ controls the current account's volatility. We employ a value for ψ that replicates the current account's standard deviation in the sample data, which is 0.9. For α and δ , we adopt 0.33 and 0.1, respectively, following King and Rebelo (1999). ϕ and θ are derived from the data: the input-output tables show that a developing country normally imports intermediate goods and investment goods for its production. We calculate ϕ and θ from the less developed economies' data as 0.174, and 0.798, respectively.⁹ \bar{L} is

⁹ The data are from the GTAP 5 Data Base (Dimaranan and Mcdougall, 2002).

standardized at unity. We select a value of η so that our model mimics the data's per capita GDP growth rate, and we set η to 19. We standardize \bar{P} at unity. \bar{A} is standardized at 0.5.

We set τ_1 , τ_2 , and σ_P^* to 0.188, 0.278, and 0.085. For the details of the calibration of these three parameters, see Appendix C.

Finally, we select a value of σ_A so that the model's standard deviation of per capita GDP growth rate becomes closer to the actual data, and we set σ_A to 0.0365.¹⁰ These parameter values are summarized in Table 4.

Table 4

3.4. Simulation Results

In this subsection, we examine whether our hypothesis produces a negative correlation between economic growth and business cycle. For the purpose, we compare the results of the two models: a model that includes Revised Assumption 1 (i.e., our negative-correlation hypothesis) and a model that does not include Revised Assumption 1. Based on this comparison, we analyze whether Revised Assumption 1 produces the negative correlation. As explained in Appendix A, the standard deviation of P (=

¹⁰ For the value of the actual data of the per capita GDP's standard deviation, we refer to the average of the cross-country data used in Section 2.

1/TOT) takes the same value as the standard deviation of TOT. For simplicity of explanation, we hereafter use terms of standard deviation of TOT and TOT volatility, instead of those of P .

Table 5 displays the average per capita GDP growth rates across periods, the standard deviation of the per capita GDP growth rates, and the standard deviations of TOT, in our benchmark simulation.

Table 5

We run a simulation for 40 periods, which corresponds to the sample data's duration (40 years). We execute the 40-period simulation 100 times. We then calculate the three indices above in each of the 100 simulations. From the 100 observations of the three indices, we calculate the averages of each of the three indices. The values in "Model" in Table 5 are these averages of the benchmark simulation. The three indices of "Data" in Table 5 are the averages across countries. For the data source, see Appendix A.

Next we run various simulations that have different economic growth rates and business cycles, and we examine whether those simulations produce a negative correlation between the economic growth rate (per capita GDP growth rate) and the business cycle.

When we set the correlation between economic growth rates and initial per capita GDPs in our simulations, we presume that there is no correlation between these variables

based on the empirical results in Table 2 and previous studies on absolute convergence.

Similarly to the benchmark case in Table 5, we run simulations 100 times for a set of the parameters, employing 100 different sets of shocks' (i.e., A 's and P 's) realizations. We refer to averages of these 100 simulations as simulation results in each of the sets of the parameters. Because the economic growth rate and initial per capita GDP are not parameters in our model, we cannot control them directly. To control them, we utilize \bar{A} and the initial value of K . There is an infinite number of combinations of \bar{A} and initial K , which reproduce a certain level of an initial per capita GDP. The different combinations produce different economic growth rates, and we choose one of the combinations that closely matches our target economic growth rate. Changing \bar{A} and initial K across simulations is not an unrealistic assumption: previous empirical studies on economic growth find that \bar{A} and K can be different across countries even if the countries' per capita GDPs are the same (see, for example, Islam, 1995; Klenow and Rodriguez-Clare, 1997; Hall and Jones, 1999).

We change economic growth rates and initial per capita GDPs across the simulations by using different sets of the parameters. To reflect the data's dispersion of the economic growth rates and the initial per capita GDPs in our simulations, we utilize the data's standard deviations of the economic growth rate and the initial per capita GDP. Let σ_g

and σ_{yini} represent the standard deviation of the economic growth rate and the initial per capita GDP, respectively. For detailed explanation on the derivation of σ_{yini} and σ_g , see Appendix C. We let \bar{g} and \bar{y}_{ini} denote the average economic growth rate of our benchmark simulation and the average initial per capita GDP of the benchmark simulation, respectively. We then simulate three cases around the average economic growth rate: \bar{g} , $\bar{g} + 0.1\sigma_g$, and $\bar{g} - 0.1\sigma_g$. We also simulate three cases around the average initial per capita GDP: \bar{y}_{ini} , $\bar{y}_{ini} + 0.1\sigma_{yini}$ and $\bar{y}_{ini} - 0.1\sigma_{yini}$. In total, we simulate nine different cases (3×3 cases) around the cross-country average. The combination of (\bar{g}, \bar{y}_{ini}) corresponds to our benchmark simulation employed in Table 5. Fig. 1 summarizes our simulation results.

Fig. 1

The upper two panels of Fig. 1 are scatter diagrams on the relationship between initial per capita GDPs and economic growth rates that correspond to the relationship examined in the literature on absolute convergence. The lower two panels are scatter diagrams of our focusing relationship, that is, the relationship between economic growth rate and business cycle. In both “Case (i)” and “Case (ii)” of Fig. 1, we presume that there is no correlation between the initial per capita GDP and the economic growth rate. The no-correlation presumption reflects our empirical result in Table 2 and the results of

previous studies on absolute convergence. In Case (i), we employ our DGE model including Assumption 1 (Eq. (12)). The lower panel of Case (i) clearly shows that economic growth rate and business cycle are negatively correlated. In Case (ii), we employ our DGE model NOT including Assumption 1.¹¹ In this case, in the lower panel, we do not observe any clear correlation.¹² The comparison of Case (i) and Case (ii) tells us that the negative correlation between the per capita GDP level and TOT volatility (Assumption 1) produces the negative correlation between economic growth rate and business cycle in Case (i).

The negative correlation between per capita GDP level and TOT volatility is not a standard assumption of a DGE model. We found this non-standard negative correlation plays a key role in producing the negative correlation between economic growth and business cycle. Furthermore, the empirical validity of Assumption 1 was confirmed in Subsection 3.1. Therefore, it is expected that the negative correlation between the per capita GDP level and TOT volatility (Assumption 1) produces the negative correlation

¹¹ In Case (ii) we adjust the standard deviation of GDP so that the value becomes approximately the same as the standard deviation of Case (i) of the benchmark case, by controlling σ_p^* .

¹² In the lower panel of Case (ii), there is not dispersion in the vertical direction whereas there is dispersion in the lower panel of Case (i). The dispersion in Case (i) is caused by the influence of initial GDP on TOT volatility (which eventually affects macroeconomic volatility as well). Meanwhile, in Case (ii), initial GDP does not affect TOT volatility because per capita GDP level does not affect TOT volatility by assumption. As a result, the lower panel of Case (ii) does not have dispersion in vertical direction.

between economic growth rate and business cycle in the actual economy as well.

4. Conclusion

It is well known that a negative correlation between economic growth and business cycle exists in cross-country data. A vast amount of scholarship has been devoted to the problem of the negative correlation. In this paper, we examine the mechanism of the negative correlation.

This research suggests the following three points. First, this research proposes a new hypothesis on the negative correlation between economic growth and business cycle. The negative-correlation hypothesis introduced in Subsection 2.1 has not been previously examined in the literature.

Second, our econometric analysis supports the hypothesis. We empirically evaluate the following two aspects: whether an influence from economic growth to business cycle exists and whether relationships between the economic variables that are stated in the hypotheses exist. The results of the econometric analyses show that the data support the existence of an influence direction from GDP growth to business cycle. The data confirm all the relationships that are presumed in our hypothesis as well.

Third, we show that our DGE analysis sustains our negative-correlation mechanism. For

the analysis, we construct a model that reflects the hypothesis, and we examine whether the model successfully produces the negative correlation between economic growth and business cycle. The results of the analysis show that the hypothesis produces the negative correlation. A negative correlation between per capita GDP level and TOT volatility is not a commonly presumed relationship in building a DGE model. We find this non-commonly presumed negative correlation plays a key role in producing the negative correlation between economic growth and business cycle.

Based on these analyses, we conclude that the mechanism considered in our hypothesis explained in Subsection 2.1 affects the production of the negative correlation between economic growth and business cycle. More specifically, we explained a mechanism of how per capita GDP level and TOT volatility are negatively correlated in Subsection 2.1, and statistically confirmed the mechanism in Subsection 2.2 and 3.1. We conclude that this negative correlation between per capita GDP level and TOT volatility produces the negative correlation between economic growth and business cycle.

At this point, we need to be careful about the relationship between our hypothesis and previously proposed hypotheses. The mechanism that is considered in our hypothesis is distinct from previous hypotheses. Nevertheless, our hypothesis does not necessarily deny the previously proposed hypotheses; it is very likely that they coexist, and their

relationship may be complementary in accounting for the growth-cycle negative-correlation phenomenon.

This research suggests the following policy implication. A developing country can reduce business cycle by stimulating economic growth. However, not all economic growth reduces business cycle. An economic growth that is dependent on considerably limited industries does not have a business cycle stabilization effect. In contrast, an economic growth that includes the development of various export-goods sectors reduces business cycle.

Appendix A. Data source and description

The sample period of all data is 1966-2005, except the data of the regressions (3) and (4) in Table 1. For the regressions (3) and (4), the data availability of “EX Variety” before 1995 is very limited. We then employ data after 1995, for the regressions (3) and (4). “EX Variety” in these two regressions is calculated as an average of this index in 1995, 2000, and 2005. The sample period of “GDP” and “TOT SD” in these two regressions is 1995-2005.

Lists of the countries adopted in this research are summarized in Appendix D. When the number of a country’s available observations is less than 75% of the entire sample, we exclude the country from our dataset. Outliers are excluded based on the Smirnov-Grubbs test. If a country satisfies one of the following two conditions, we regard the country as an extremely oil-dependent country, and we exclude the country from our dataset: 1) the ratio of oil export to GDP is higher than 30%, and 2) the ratio of oil export to the entire export is higher than 80%.

GDP

Source: Penn World Table 6.3

Note: RGDPCH in the dataset. The data is constant-price per capita GDP in PPP US\$.

Growth: GDP growth rate

Source: Penn World Table 6.3

Note: Growth rate of "GDP" above. Growth rate is calculated as a difference in natural logarithm.

GDP SD: Standard deviation of GDP

Source: Penn World Table 6.3

Note: Standard deviation of "Growth" above.

Ini GDP: Initial GDP

Source: Penn World Table 6.3

Note: Value of “GDP” in 1966 which is the initial year of our sample period (1966-2005).

TOT SD: Standard deviation of TOT

Source: World Development Indicators 2008

Note: From the SNA data, we derive the implicit export prices and import prices. We calculate a ratio of export prices to import prices, which is TOT. We detrend the TOT data with the first difference filter. We then measure the standard deviation of the detrended TOT.

EX Variety: Index of export good variety

Source: UN comtrade, merchandise export based on SITC three-digit codes in 1995, 2000, and 2005

Note: This index is a type of Gini coefficient. In the original Gini coefficient, we measure the extent of equality of income distribution. By contrast, in “EX Variety,” we measure the extent of equality of export value distribution among SITC’s export items. A larger “EX Variety” implies the target country has more various main export goods. This characteristic arises from the subsequent derivation procedure.

The derivation procedure of this index is similar to that of the Gini coefficient. First, for SITC three-digit items in merchandise export, we calculate each item's share of the total export. Second, we divide all the shares by the number of items of the SITC three-digit codes. Note that “the number of items of the SITC three-digit codes” includes the number of zero-share items. Third, we order the calculated shares, divided by the number of items, from the smallest to the largest. We then calculate the cumulative divided shares from the smallest item to the target items; the cumulative divided shares from the smallest item to the smallest item, from the smallest item to the second smallest item, from the smallest item to the third smallest item, and so forth. Fourth, as the final step, we aggregate all of these cumulative divided shares. This aggregated value is used as an index of export good variety in our research.

When deriving a conventional Gini coefficient, we subtract the doubled aggregated value from unity.

However, we do not perform the subtraction in the derivation of “EX Variety.” As a result, if the index of a country is large, it suggests that the export value of the target country is evenly distributed across the SITC three-digit items. In other words, if this index is large, the country has a variety of export goods.

Regional Dummy

Note: We use, in the first stage regression of the two stage least squares, three regional dummy variables: East and Southeast Asia, South Asia, and North Africa. The corresponding countries are as follows:

East and Southeast Asia: Cambodia, China, Indonesia, Laos, Malaysia, Mongolia, Myanmar, Philippines, Thailand, Vietnam

South Asia: Bangladesh, Bhutan, India, Nepal, Pakistan, Sri Lanka

North Africa: Algeria, Egypt, Libya, Morocco, Sudan, Tunisia

Index of geography

Note: An index that expresses how closely to tropical areas a country is located. If this index of a country is small, it means the country is located closely to the tropical areas. For the derivation of this index, see Bosworth and Collins (2003).

Standard deviation of P

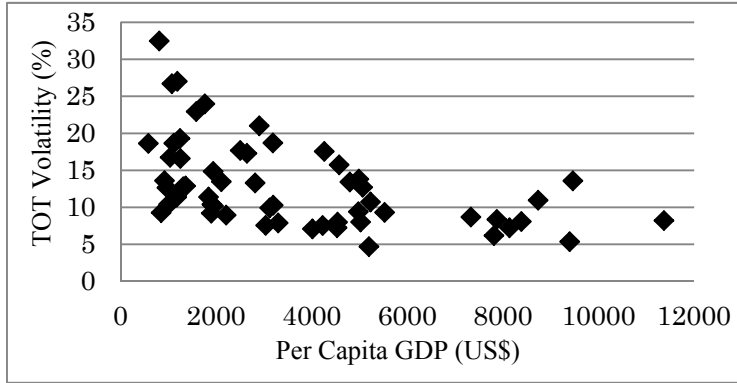
Note: This index’s value is equal to “TOT SD” (standard deviation of TOT) because the detrended TOT and detrended P ($=1/TOT$) become the same. For details of this index’s derivation, see “TOT SD”.

Appendix B. Scatter diagram of per capita GDP – TOT volatility

The following diagram illustrates a scatter diagram of a relationship between per capita

GDP and TOT volatility. TOT volatility refers to standard deviation of TOT. For details

of per capita GDP and standard deviation of TOT, see Appendix A.



Appendix C. Calibration of τ_1 , τ_2 , σ_p^* , σ_g , and σ_{yini}

First, we refer to the empirical results in Subsection 3.1. The first column in Table 3 shows that TOT volatility decreases corresponding to per capita GDP's expansion when per capita GDP is small. We write the relationship, estimated in the first column of Table 3, as Eq. (C.1).

$$\sigma_{TOT}^{data} = 0.188 - 1.82 \times 10^{-5} \cdot y^{data} \quad (C.1)$$

σ_{TOT}^{data} and y^{data} express standard deviation of TOT and per capita GDP in the actual data, respectively. The second column of Table 3 tells that per capita GDP expansion does not reduce TOT volatility when per capita GDP is large. Furthermore, according to the diagram in Appendix B, the TOT volatility in this region seems to distribute around the minimum of TOT volatility of the region of Eq. (C.1) where per capita GDP is small.

$\sigma_{TOT}^{min,data}$ denotes the data's average of TOT standard deviation in the second region where per capita GDP is large. Now we write this result as an equation.

$$\sigma_{TOT}^{data} = \sigma_{TOT}^{min,data}. \quad (C.2)$$

Suppose we plot diagrams of these two equations in a plane of which horizontal and vertical axes are y^{data} and σ_{TOT}^{data} . These two equations meet at a point. $y^{*,data}$ and $\sigma_{TOT}^{*,data}$ denote y^{data} and σ_{TOT}^{data} at this threshold point. Meanwhile, we define $\sigma_{TOT}^{max,data}$ as σ_{TOT}^{data} of which corresponding y^{data} is equal to zero. We calculate $\sigma_{TOT}^{max,data}$ from Eq. (C.1). From these procedure, Eq. (C.1) goes through two coordinates of $(y^{*,data}, \sigma_{TOT}^{*,data})$ and $(0, \sigma_{TOT}^{max,data})$. We refer to this empirical information in the next step.

Second, we choose values of some parameters in our model. Note that standard deviations of TOT and our model's $P (=1/TOT)$ take the same values (see Appendix A).

We choose a candidate value of y 's (i.e. per capita GDP's) cross-period average in our model ($y^{mean,model}$). We also choose a candidate value of initial value of y in our model. Referring to the ratio between y 's average in the data ($y^{mean,data}$) and $y^{*,data}$, we choose y^* 's value in our model ($y^{*,model}$) so that $y^{*,model}$ satisfies the following equation: $y^{*,model}/y^{mean,model} = y^{*,data}/y^{mean,data}$. Next we determine τ_1 and τ_2 . In the data, when the per capita GDP increases from zero to per capita GDP's threshold, TOT volatility decreases by $\sigma_{TOT}^{max,data} - \sigma_{TOT}^{*,data}$. We then choose τ_1 and τ_2 so that TOT's volatility in the model decreases by $\sigma_{TOT}^{max,data} - \sigma_{TOT}^{*,data}$ when per capita GDP

in the model increases from zero to its threshold. σ_p^* in Eq. (12) is set to $\sigma_{TOT}^{*,data}$.

Third, we adjust our parameters, based on simulation results. We run simulations, and then compare the cross-period average of y simulated in our model and the cross-period average of y chosen in the second step of this calibration procedure. If they are very different, we re-do the calculation, using another candidate values of average y and initial y in our model. If they take approximately same values, we stop the calculation and adopt parameters used in the simulation as our benchmark parameters.

For σ_{yini} and σ_g , we derive them as follows. We write σ_{yini} of the data and initial y of the data as σ_{yini}^{data} and y_{ini}^{data} . Suppose we have an initial value of y in our model (y_{ini}^{model}), based on the procedure introduced above. We choose σ_y of the model (σ_y^{model}) so that σ_y^{model} satisfy the following equation.

$$\sigma_{yini}^{model}/y_{ini}^{model} = \sigma_{yini}^{data}/y_{ini}^{data}$$

We determine the value of σ_g in a similar way.

Appendix D. Sample countries

‘a,’ ‘b,’ ‘c,’ ‘d,’ and ‘e’ represent availabilities of a country’s data in the regressions (1), (2), (3), (4), and (5) in Table 1. ‘f’ and ‘g’ represent availabilities in the regressions (1) and (2) in Table 2. ‘h’ and ‘i’ represent availabilities in the regressions (1) and (2) in Table 3.

Afghanistan ^{a, b, g}	Albania ^{a, g}	Antigua and Barbuda ^{a, g}
Argentina ^{a, b, e, f, g, i}	Bangladesh ^{a, b, c, d, e, f, g, h}	Belize ^{a, b, c, d, g}
Benin ^{a, b, c, d, e, f, g, h}	Bhutan ^{a, b, g}	Bolivia ^{a, b, c, d, e, f, g, h}
Botswana ^{a, b, e, f, g, h}	Brazil ^{a, b, c, d, e, f, g, i}	Bulgaria ^{a, g}
Burkina Faso ^{a, b, c, d, e, f, g, h}	Burundi ^{a, b, c, e, f, g, h}	Cambodia ^{a, b, g}
Cameroon ^{a, b, c, d, e, f, g, h}	Cape Verde ^{a, b, f, g}	Central Africa ^{a, b, c, f, g}
Chad ^{a, b, f, g}	Chile ^{a, b, c, d, e, f, g, i}	China ^{a, b, c, d, f, g}
Colombia ^{a, b, c, d, e, f, g, h}	Comoros ^{a, b, f, g}	Congo, DR ^{a, b, e, f, g, h}
Congo, R. ^{a, b, e, f, g, h}	Costa Rica ^{a, b, c, d, e, f, g, i}	Cote d'Ivoire ^{a, b, c, d, e, f, g, h}
Cuba ^{a, b, g}	Djibouti ^{a, b, g}	Dominica ^{a, g}
Dominican R. ^{a, b, e, f, g, h}	Ecuador ^{a, b, c, d, e, f, g, h}	Egypt ^{a, b, c, d, e, f, g, h}
El Salvador ^{a, b, c, d, e, f, g, h}	Ethiopia ^{a, b, f, g}	Fiji ^{a, f, g}
Gambia ^{a, b, c, d, e, f, g, h}	Ghana ^{a, b, e, f, g, h}	Grenada ^{a, g}
Guatemala ^{a, b, c, d, e, f, g, h}	Guinea ^{a, b, f, g}	Guinea-Bissau ^{a, b, c, d, e, f, g, h}
Guyana ^{a, b, e, g, h}	Haiti ^{a, b, f, g}	Honduras ^{a, b, c, d, e, f, g, h}
India ^{a, b, c, d, e, f, g, h}	Indonesia ^{a, b, c, d, e, f, g, h}	Iraq ^g
Jamaica ^{a, b, c, f, g}	Jordan ^{a, e, f, g, h}	Kenya ^{a, b, c, d, e, f, g, h}
Kiribati ^{a, g}	Laos ^{a, b, g}	Lebanon ^g
Lesotho ^{a, b, e, f, g, h}	Liberia ^g	Madagascar ^{a, b, c, d, e, f, g, h}
Malawi ^{a, b, c, d, e, f, g, h}	Malaysia ^{a, b, c, d, e, f, g, i}	Maldives ^{a, g}
Mali ^{a, b, e, f, g, h}	Marshall Is. ^{a, g}	Mauritania ^{a, c, d, e, f, g, h}
Mauritius ^{a, b, e, f, g, i}	Mexico ^{a, b, c, d, e, f, g, i}	Micronesia ^{a, g}
Mongolia ^{a, b, g}	Morocco ^{a, b, c, d, e, f, g, h}	Mozambique ^{a, b, f, g}
Namibia ^{a, b, f, g}	Nepal ^{a, b, f, g}	Nicaragua ^{a, b, c, d, e, f, g, h}
Niger ^{a, b, c, e, f, g, h}	Pakistan ^{a, b, c, d, e, f, g, h}	Palau ^a
Panama ^{a, b, c, d, f, g}	Papua N. G. ^{a, b, e, f, g, h}	Paraguay ^{a, b, c, d, e, f, g, h}
Peru ^{a, b, c, d, e, f, g, h}	Philippines ^{a, b, c, d, e, f, g, h}	Romania ^{a, f, g}
Rwanda ^{a, b, e, f, g, h}	Samoa ^{a, g}	Sao Tome and Principe ^{a, g}
Senegal ^{a, b, e, f, g, h}	Seychelles ^{a, c, d, f, g}	Sierra Leone ^{a, b, f, g}
Solomon Islands ^{a, g}	Somalia ^{a, b, g}	South Africa ^{a, e, f, g, i}
Sri Lanka ^{a, b, f, g}	St. Kitts and Nevis ^{a, g}	St. Lucia ^{a, g}
St. Vincent and Grenadines ^{a, c, d, g}	Sudan ^{a, b, c, d, e, g, h}	Suriname ^{a, b, g}
Swaziland ^{a, b, c, d, e, g, h}	Syria ^{a, b, c, d, f, g}	Tanzania ^{a, f, g}
Thailand ^{a, b, c, d, e, f, g, h}	Togo ^{a, b, c, d, e, f, g, h}	Tonga ^{a, g}
Tunisia ^{a, b, c, d, e, f, g, h}	Turkey ^{a, b, c, d, f, g}	Uganda ^{a, b, f, g}
Uruguay ^{a, b, c, d, e, f, g, i}	Vanuatu ^{a, g}	Vietnam ^{a, b, g}
Zambia ^{a, b, c, d, e, f, g, h}	Zimbabwe ^{a, b, c, d, e, f, g, h}	

References

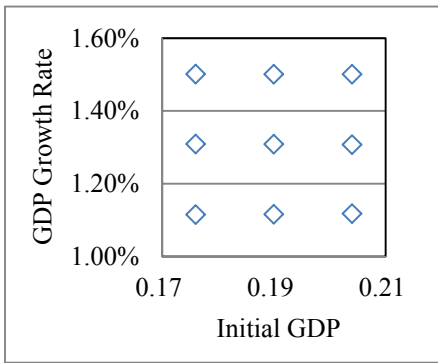
- Badinger, H., 2010. Output volatility and economic growth. *Economics Letters* 106, 15-18.
- Barro, R.J., Sala-i-Martin, X., 2003. *Economic Growth*, second ed. MIT Press, Cambridge.
- Bosworth, B., Collins, S., 2003. The empirics of growth: An update. *Brookings Papers on Economic Activity* 4, 136-147.
- Bruton, H.J., 1998. A reconsideration of import substitution. *The Journal of Economic Literature* 36, 903-993.
- Dimaranan, B.V., McDougall, R.A., 2002. *Global trade, assistance, and production: The GTAP 5 Data Base*. Center for Global Trade Analysis, Purdue University, West Lafayette.
- Hall, R.E., Jones, C.I., 1999. Why do some countries produce so much more output per worker than others? *The Quarterly Journal of Economics* 114, 83-116.
- Heston, A., Summers, R., Aten, B., 2009. *Penn World Table Version 6.3*. Center for International Comparisons of Production, Income and Prices at the University of Pennsylvania, Philadelphia.
- Hnatkovska, V., Loayza, N., 2004. *Volatility and growth*, Policy Research Working

- Paper Series. The World Bank, Washington DC.
- Imbs, J., 2007. Growth and volatility. *Journal of Monetary Economics* 54, 1848-1862.
- Islam, N., 1995. Growth empirics: A panel data approach. *The Quarterly Journal of Economics* 110, 1127-1170.
- King, R.G., Rebelo, S.T., 1999. Resuscitating real business cycles, in: Taylor, J.B., Woodford, M. (Eds.), *Handbook of Macroeconomics*, Vol. 1. North Holland, Amsterdam, pp. 927-1007.
- Klenow, P., Rodríguez-Clare, A., 1997. The neoclassical revival in growth economics: Has it gone too far?, *NBER Macroeconomics Annual 1997*, Vol. 12. MIT Press, Cambridge, pp. 73-114
- Kose, M.A., 2002. Explaining business cycles in small open economies: How much do world prices matter? *Journal of International Economics* 56, 299-327.
- Lee, J., 2010. The link between output growth and volatility: Evidence from a GARCH model with panel data. *Economics Letters* 106, 143-145.
- Loayza, N.V., Ranciere, R., Servén, L., Ventura, J., 2007. Business cycle and welfare in less developed economies: An introduction. *The World Bank Economic Review* 21, 343-357.
- Martin, P., Rogers, C.A., 2000. Long-term growth and short-term economic instability.

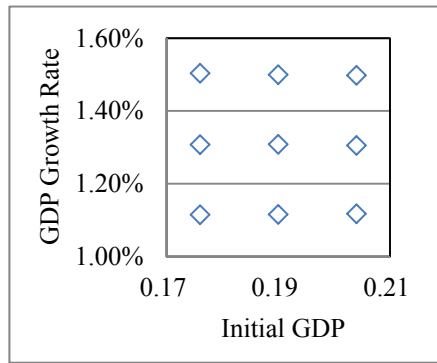
- European Economic Review 44, 359-381.
- Mendoza, E.G., 1995. The terms of trade, the real exchange rate, and economic fluctuations. *International Economic Review* 36, 101-137.
- Mody, A., Yilmaz, K., 2002. Imported machinery for export competitiveness. *World Bank Economic Review* 16, 23-48.
- Ostry, J.D., Reinhart, C.M., 1992. Private saving and terms of trade shocks: Evidence from less developed economies. *Staff Papers - International Monetary Fund* 39, 495-517.
- Ramey, G., Ramey, V.A., 1995. Cross-country evidence on the link between volatility and growth. *The American Economic Review* 85, 1138-1151.
- Schmitt-Grohe, S., Uribe, M., 2003. Closing small open economy models. *Journal of International Economics* 61, 163-185.
- Turnovsky, S.J., Chattopadhyay, P., 2003. Volatility and growth in developing economies: Some numerical results and empirical evidence. *Journal of International Economics* 59, 267-295.
- United Nations, UN comtrade. United Nations, New York.
- World Bank, 2008. World Development Indicators on CD-ROM. World Bank, Washington DC.

Absolute Convergence

Case (i): Model with Assumption 1

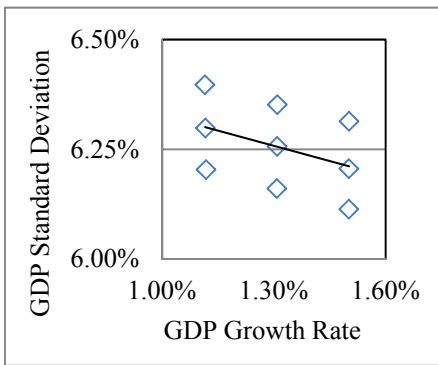


Case (ii): Model without Assumption 1



Growth – Volatility Correlation

Case (i): Model with Assumption 1



Case (ii): Model without Assumption 1

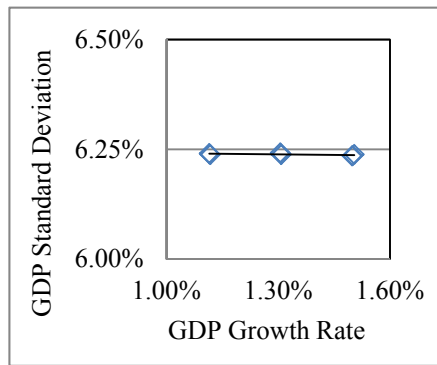


Fig. 1. Simulation results.

Table 1

Link between GDP level and TOT volatility.

	(1)	(2)	(3)	(4)	(5)
Dependent Variable	GDP SD	GDP SD	EX Variety	TOT SD	GDP SD
Method	OLS	2SLS	OLS	OLS	OLS
Explanatory Variable	Growth	Growth	GDP	EX Variety	TOT SD
Coefficient	-0.60 ^{***}	-0.63 ^{**}	5.29×10 ^{-6**}	-0.29 ^{***}	0.18 ^{***}
	(0.14)	(0.29)	(2.17×10 ⁻⁶)	(0.10)	(0.06)
R ²	0.14	0.14	0.11	0.17	0.15
Observations	107	82	50	46	56

Source: See Appendix A.

Note: 1) “GDP” represents per capita GDP. “Growth” represents the per capita GDP growth rate. “GDP SD” represents the standard deviation of the per capita GDP growth rates. “EX Variety” represents an export-good-variety index that becomes large if a target country has various export goods. For a detailed explanation of this index, see Appendix A. “TOT SD” represents the standard deviation of the terms of trade growth rates. 2) An intercept term is included in all regressions. 3) ‘***’, ‘**’, and ‘*’ stand for significance levels of 1%, 5%, and 10%, respectively. 4) Standard errors are reported in parenthesis.

Table 2

Link between GDP growth and GDP level.

Dependent Variable	(1) Growth	(2) GDP
Explanatory Variable	Ini GDP	Growth
Coefficient	-6.76×10^{-7} (1.09×10^{-6})	3.91×10^4 *** (1.34×10^4)
Intercept Term	0.01*** (3.38×10^{-3})	3.29×10^3 *** (3.10×10^2)
R ²	< 0.01	0.07
Observations	75	109

Source: See Appendix A.

Note: 1) “GDP” represents per capita GDP. “Growth” represents the per capita GDP growth rate. “Ini GDP” represents the initial GDP of the sample period. 2) The estimation method is OLS. 3) ‘***’, ‘**’, and ‘*’ stand for significance levels of 1%, 5%, and 10%, respectively. 4) Standard errors are reported in parenthesis.

Table 3

Empirical validities of Revised Assumption 1.

Dependent Variable	(1)	(2)
	TOT SD < Threshold	TOT SD ≥ Threshold
GDP's Range		
Explanatory Variable	GDP	GDP
Coefficient	-1.82×10^{-5} ^{***} (5.04×10^{-6})	3.12×10^{-6} (7.55×10^{-6})
Intercept Term	0.188 ^{***} (0.016)	0.058 (0.066)
R ²	0.23	0.02
Observations	47	9

Source: See Appendix A.

Note: 1) Revised Assumption 1 postulates two types of relationships: (i) "Coefficient" is negative and significant if "GDP" < "Threshold." (ii) "Coefficient" is close to zero if "GDP" ≥ "Threshold." The "Threshold" of the per capita GDP is US\$5525. 2) The estimation method is OLS. "GDP" represents per capita GDP. "TOT SD" represents the standard deviation of the terms of trade's growth rates. 3) ^{***}, ^{**}, and ^{*} stand for significance levels of 1%, 5%, and 10%, respectively. 5) Standard errors are reported in parenthesis.

Table 4

Parameters.

Consumption	$\beta=0.96; \gamma=2.61; r=1/\beta-1; \psi=0.9; \bar{B}=0$
Production	$\alpha=0.33; \phi=0.174; \bar{L}=1; \eta=19; \theta=0.798; \delta=0.1$
Shock Process	$\tau_1=0.188; \tau_2=0.278; \sigma_p^*=8.50 \times 10^{-2}; \sigma_A=3.65 \times 10^{-2}; \bar{A}=0.5; \bar{P}=1$

Note: For detailed explanations, see Subsection 3.3.

Table 5

Results of the benchmark simulation.

	\bar{A}	Growth	SD(GDP)	SD(TOT)
Model	0.50	1.31%	6.26%	11.64%
Data	-	1.32%	6.25%	13.03%

Source: For the source of “Data”, see Appendix A.

Note: “ \bar{A} ” represents the average productivity level. “Growth” represents the per capita GDP growth rate. “SD(GDP)” represents the standard deviation of the per capita GDP growth rates. “SD(TOT)” represents the standard deviation of TOT. As explained in Appendix A, SD(TOT) and the standard deviation of the relative imported prices’ (P ’s) growth rates take same values.