Growth volatility and technical progress: a simple rent-seeking model*

Charles Ka Yui Leung, Sam Hak Kan Tang and Nicolaas Groenewold †

October 26, 2005

Abstract

Recent empirical evidence demonstrates that a higher level of technical

progress is associated with a lower level of growth volatility and higher expected economic growth. This paper builds a simple growth model which combines the insights of Angeletos and Kollintzas (2000) and Tse (2000, 2001, 2002) with endogenous productivity growth and rent-seeking behavior to account for these stylized facts. Our model also complements the literature that focuses on the heterogeneity of different agents. Future research directions are also discussed.

JEL classification: E30, O11, O40

keywords: volatility of economic growth, technical progress, rent-seeking, stabilization policy, institution.

---

*Acknowledgement: The authors thank Kai-Sun Kwong, and especially the anonymous referees, the Editor, for helpful comments, Fulbright Foundation (Leung), the Chinese University of Hong Kong Direct Grant for financial support (Tang). The usual disclaimer applies.

†Correspondence. Leung: Department of Economics, The Chinese University of Hong Kong, Shatin, NT, Hong Kong, (Phone) (852)-2609-8194; (Fax) (852)-2603-5805; Email: charlesl@cuhk.edu.hk; Tang and Groenewold: Department of Economics, The University of Western Australia, 35 Stirling Highway, Crawley WA 6009, Australia, Email: stang@biz.uwa.edu.au, sam.tang@uwa.edu.au, nic.groenewold@uwa.edu.au.

1 Introduction

This paper attempts to develop a simple growth model which relates the volatility of economic growth and technical progress (or *total factor productivity growth*, or simply *TFPG*). Recently, there has been a growing interest in the relationship between the volatility of the aggregate output and other macroeconomic variables.[1] For instance, Ramey and Ramey (1995) find that the (average) economic growth rate and the volatility of GDP are negatively correlated. Knack and Keefer (1995) and Acemoglu, Johnson, and Robinson (2001, 2002), among others, find that higher institutional quality has a positive effect on economic growth. Acemoglu et. al. (2003) find further that higher institutional quality helps to reduce growth volatility and mitigate economic crises. De Hak (1999) and Blackburn and Galindev (2003) provide growth models which relate macroeconomic volatility and the rate of economic growth. They do not, however, directly relate the technical progress, economic growth and growth volatility. Aghion and Banerjee (2005) argue that it is the interaction between the entrepreneurs and the imperfect capital market which leads to both the business cycle and economic growth. However, most, if not all, of these papers have not related volatility to the productivity of the economy. Tang (2002) is perhaps the first cross-country study which establishes that the higher the rate of technical progress, the lower will be the volatility of economic growth rate. Tang, however, does not provide a theory for this empirical regularity.

This paper attempts to explain the relationship between technical progress, macroeconomic volatility and growth by using a simple endogenous growth model with rent-seeking behavior. The analysis is clearly connected to a growing literature on how the endogenous career choice between productive entrepreneurship and rent-seeking behavior can influence aggregate output. For instance, Baumol (1990) provides many historical examples which show that the returns to rent-seeking can affect the allocation of entrepreneurship. Murphy, Shleifer and Vishny (1991) study how the heterogeneity of agents can interact with the rent-seeking and lead to a lower economic growth rate.[2] Acemoglu and Verdier (1998) present a rich model on the endogenous choice of rent-seeking. However, perhaps due to the finite-horizon nature of their model, they do not explore how rent-seeking activities interact with the determination of economic growth.[3] Tse (2000) carefully calibrates a two-sector general equilibrium model and finds that GDP can increase by more than 2 times if monopoly is removed from the labor market. In a companion paper, Tse (2002) shows that monopoly in the capital equipment market can also affect employment as well as wages, and hence has important welfare consequences. Tse (2001) shows that the distribution of demand can significantly change the incentives of firms to invest

[1] For instance, see Aghion and Saint-Paul (1998) for a survey.

[2] In addition, Kwong et. al. (2001) provide evidence that the industrial policies in Singapore and South Korea have led to discrimination against small and medium size enterprises, a lack of initiative and government-dependency among the citizens. In the case of South Korea, it has been argued that it even leads to corruption.

[3] See Rebelo (1998) for a detailed discussion on the determinants of economic growth.

and innovate. It follows that firms indeed have incentives to influence the distribution of demand. Finally, Tse (2004) shows how informational friction can create market power for firms, thus adversely affecting capital accumulation and long-run economic growth. This paper takes a preliminary step to show how rent-seeking activities, which would create some market power for the firms, may *not only affect the rate of the economic growth, but also its volatility.*

Since both the economic growth rate and its volatility are the subjects of our investigation, they need to be endogenized in the model. Thus, the model necessarily belongs to the family of stochastic, endogenous growth models.[4] The existing literature, however, is more concerned with the time series implications of a typical stochastic endogenous growth model and how these time series implications can be verified, while this paper focuses on how different institutions could affect the (stochastic) time series properties of a growth model, such as the average growth rate and the volatility of GDP.

Economists have long been aware of the problem of rent-seeking and the literature which has accumulated is voluminous.[5] Recent efforts have explored several important issues, such as the strategic interactions among potentially rent-seeking entrepreneurs, the role of constitutions and institutions; and the importance of the initial distribution of wealth, all of which would affect the aggregate economic outcomes.[6] The present paper builds on the work of Angeletos and Kollintzas (2000) but modifies their model in two important ways.[7] First, this paper abstracts from the capital accumulation, which is important for the convergence result in Angeletos and Kollintzas (2000).[8] Since this paper focuses on the mean and variance of the economic growth rate, we suppress this concern. Instead, we endogenizes the economic growth by introducing a simple R&D technology.[9] A merit of this framework is that it can endogenously derive the relationship between rent-seeking and the economic growth rate within a representative household framework. Certainly, the heterogeneity of agents, externality effects, income distribution and redistribution issues are important in understanding the role of rent-seeking in practice. Nevertheless, to complement the existing contribution and to highlight the rent-seeking activities among firms, this simple model abstracts from these factors and focuses merely on the simple, resource allocation consideration which leads to the emergence of rent-seeking.[10]

It should be noticed that the significance of this research may go beyond establishing and explaining another stylized fact in growth, namely, a robust

[4] For instance, see Leung and Quah (1996), Quah (1996, 1997), Lau (1999).

[5] It is beyond the scope of this paper to survey that literature. Among others, see Buchanan, Tollison and Tullock (1980), Eicher and Garcia-Penalosa eds (2005), Tullock (1993). Tullock (2003) provides an account of the term "rent-seeking".

[6] Among others, see Drazen (2000) and Persson and Tabellini (2000) for a textbook treatments.

[7] To be internally consistent, there are some minor amendments as well.

[8] This follows a referee's suggestion which we gratefully acknowledge.

[9] This follows another referee's suggestion which we also gratefully acknowledge.

[10] See Angeletos and Kollintzas (2000, footnote 8) for more discussion on the role of heterogeneity in understanding the relationship between rent-seeking and growth.

negative relationship between TFPG and growth volatility.[11] Specifically, if we regard growth fluctuation as a "bad" thing for the economy, then it may be a reasonable government objective to eliminate at least part of this "bad" thing, by improving TFPG of the overall economy.[12] Consequently, it may provide an additional justification for various forms of government subsidies to R&D, since these subsidies promote TPPG and therefore help to "stabilize" growth fluctuations.[13]

The organization of this paper is simple. The next section presents some stylized facts. Then a simple stochastic, dynamic general equilibrium model is built. The paper will provide conditions under which (endogenous) technical progress is positively correlated to the rate of economic growth, and at the same time negatively correlated with the volatility of economic growth rate. We summarize and conclude in the last section. Detailed proofs are provided in the appendix.

2 Some Stylized Facts

There is only limited empirical work on the relationship between growth fluctuations and technical progress, and this section draws heavily on Tang (2002) and Tang, Groenewold and Leung (2003) (henceforth TGL). Tang (2002) presents perhaps the first systematic analysis of the relationship between growth volatility and technical progress. Using four different measures of TFPG, and data from 98 different countries,[14] a robust negative relationship between growth volatility and TFPG is found. The relationship holds even when the initial per worker GDP, initial human capital stock and initial productivity gap are controlled for. Depending on the measure of TFPG being used, the point estimates of TFPG contribution range from -0.33 to -0.75, all statistically significant. Building on the work of Tang (2002), and following the methodology of Acemoglu et. al. (2003), TGL evaluate the role of technical change in affecting the macroeconomic volatility, crises and growth. Using different samples and control variables, they find that better institutional quality accelerates technical change, which in turn reduces growth volatility and mitigates economic crises. Their results are robust to a large number of alternative specifications and controls for simultaneity. Figures 1, 2 and table 1 provide a summary of their empirical results.[15]

[11] Throughout this paper, the term "productivity" and "technological progress" will be used interchangeably.

[12] There is a debate on whether the post-war aggregate fluctuations of the U.S.A. has been stablized, and whether the government policies have been effective in this respect. It is beyond the scope of this paper to survey that literature and interested readers may consult Stock and Watson (1999).

[13] There has been some discussion in the literature of the difference between the private and social return of R&D. Among others, see Jones and Williams (1998, 2000).

[14] Due to the data availability, one of the measure of the TFPG can only be calculated for 56 countries.

[15] See TGL for details.

(Figure 1, 2 and Table 1 about here)

3 A Baseline Model

This section presents a simple growth model. Time is discrete and the horizon is infinite. The economy is populated by a large number N of identical infinite-lived agents. Each agent operates their own production technology. In each period, a typical agent z, $z = 1, 2, ..., N$, maximizes the expected, discounted sum of utility

$$E_t \sum_{s=t}^{\infty} \beta^{s-t} u\left(c_s(z)\right), \tag{1}$$

where $0 < \beta < 1$, $c_t(z)$ is the consumption of the agent z at period t. For simplicity, the utility function takes the log form: $u\left(c_s(z)\right) = \ln\left(c_s(z)\right)$.[16] The representative agent maximizes (1) subject to the budget constraint and the time constraint

$$c_t(z) \leq S_t(z) y_t(z), \tag{2}$$

$$l_t^y(z) + l_t^x(z) + l_t^d(z) \leq 1, \tag{3}$$

where $S_t(z)$ is the subsidy factor for agent z, and $y_t(z)$ is the output of agent z. Clearly, if $S_t(z)$ is larger (smaller) than unity, then agent z is receiving subsidy (being taxed) in net terms. $l_t^y(z)$, $l_t^x(z)$, $l_t^d(z)$ are the fraction of time employed in productive, rent-seeking activities, and R&D respectively, which are all restricted to be positive, $l_t^y(z)$, $l_t^x(z)$, $l_t^d(z) > 0$. To highlight the importance of rent-seeking activities, we follow Angeletos and Kollintzas (2000) in assuming that the net amount of subsidy depends on the rent seeking effort of agent z relative to the average rent-seeking effort in the economy,

$$S_t(z) = \left(l_t^x(z)/L_t^x\right)^{\theta_2}, \tag{4}$$

where L_t^x is the average rent-seeking effort of the economy at time t,

$$L_t^x = \sum_{z=1}^{N} l_t^x(z)/N. \tag{5}$$

L_t^x is taken as given in agent z's maximization problem, and will be determined at the equilibrium. θ_2 is a parameter to measure the importance of rent-seeking efforts in determining the government subsidy (or tax). Clearly, if $\theta_2 = 0$, then individual rent-seeking efforts are not effective at all. We will discuss the government budget constraint later. We assume that $0 < \theta_2 < 1$.

The production side is very simple here. The output of agent z only depends on the productive effort of agent z, $l_t^y(z)$, and the aggregate productivity at time t, A_t,

$$y_t(z) = A_t \left(l_t^y(z)\right)^{\theta_1}, \tag{6}$$

[16] In the current setting, relaxing this assumption will only complicate the algebra without any additional insights.

with $0 < \theta_1 < 1$. We further impose the restriction that $\theta_1 + \theta_2 < 1$.

To solve the individual maximization problem, we proceed in two steps. First, we take the R&D effort $l_t^d(z)$ as given, and only determine the allocation between production and rent-seeking activity. We take this optimal allocation into the second step, which is to pin down the R&D effort. The first step is essentially static and it is easy to show that first order conditions imply

$$l_t^x(z) = (\theta_2/\theta_1)\, l_t^y(z). \tag{7}$$

Substituting this into (3), we have

$$\begin{aligned} l_t^y(z) &= \left(\frac{\theta_1}{\theta_1+\theta_2}\right)\left(1 - l_t^d(z)\right), \\ l_t^x(z) &= \left(\frac{\theta_2}{\theta_1+\theta_2}\right)\left(1 - l_t^d(z)\right). \end{aligned} \tag{8}$$

Thus, the net output of agent z is $S_t(z)y_t(z)$,

$$S_t(z)y_t(z) = A_t\phi\left(1 - l_t^d(z)\right)^{\theta_1+\theta_2}\left(L_t^x\right)^{-\theta_2},$$

where $\phi = \theta_1^{\theta_1}\theta_2^{\theta_2}\left(\theta_1+\theta_2\right)^{-(\theta_1+\theta_2)} > 0$.

Now we move to the second step, which is to determine the optimal time allocated to R&D activities. Since R&D affects future rather than current productivity, the maximization problem is necessarily dynamic in nature. Furthermore, to determine the optimal R&D effort, it is necessary to know the *marginal return* of investing in R&D. For simplicity, we assume that the research effort for each individual is observable to all other agents, and that aggregate productivity growth depends on the R&D efforts of *all* agents. Formally, the aggregate productivity growth rate is a random process, whose distribution takes the following form,

$$\gamma_t = \begin{cases} \Gamma_g & \text{with probability } p \\ \Gamma_b\left(\overrightarrow{l_t^d}\right) & \text{with probability } 1-p \end{cases}, \tag{9}$$

where γ_t is the growth rate of productivity between period t and $t+1$, $\gamma_t \equiv A_{t+1}/A_t$, and Γ_g is a parameter describing the growth rate in a "good state", $\Gamma_g > 1/\beta > 1$, p is an exogenously given probability, $0 < p < 1$, and $\overrightarrow{l_t^d}$ is the vector of all the individuals' efforts in R&D, $\overrightarrow{l_t^d} = \left(l_t^d(1), ..., l_t^d(z), ...\ l_t^d(N)\right)$. Notice that while the probabilities of different "states of Nature" are exogenous, the levels of the realization are endogenous.[17] To capture the idea that the level of "bad state" is increasing in any individual's effort, we have $\partial\Gamma_b\left(\overrightarrow{l_t^d}\right)/\partial l_t^d(z) > 0$, $\forall z$, and the natural restriction that the growth rate of a good state is higher than the bad state implies that $\Gamma_g > \Gamma_b > 0$, we assume that

$$\Gamma_b = \Gamma_g \prod_{z=1}^{N}\left(l_t^d(z)\right)^{1/N}. \tag{10}$$

[17] For a comparison of the moral hazard type model, see Kahn (1990), Leung (2001).

Since $1 > l_t^d(z) > 0$, $\forall z$, the desired conditions are all satisfied. In addition, this formulation will prove to be very tractable. Given all these assumptions, it is easy to see that the individual's dynamic optimization problem (i.e. maximizing (1), subject to (2), (3), and other constraints) can be written as

$$\begin{aligned} V\left(A_t; \overrightarrow{l_t^d}(-z), L_t^x\right) &= \max_{l_t^d(z)} \ln\left(A_t \phi \left(1 - l_t^d(z)\right)^{\theta_1+\theta_2} \left(L_t^x\right)^{-\theta_2}\right) \\ &\quad + \beta\left[p \cdot V\left(\Gamma_g A_t; \overrightarrow{l_{t+1}^d}(-z), L_{t+1}^x\right)\right. \\ &\quad \left. + (1-p) V\left(\Gamma_b\left(\overrightarrow{l_t^d}\right) A_t; \overrightarrow{l_{t+1}^d}(-z), L_{t+1}^x\right)\right], \end{aligned} \tag{11}$$

where $\overrightarrow{l_t^d}(-z)$ is the vector of research efforts for all agents except agent z at period t, $\overrightarrow{l_t^d}(-z) \equiv \left(l_t^d(1), ..., l_t^d(z-1), l_t^d(z+1) ... l_t^d(N)\right)$. Notice that with probability p, period $t+1$ productivity will increase to $A_{t+1} = \Gamma_g A_t$, as described by (9). Clearly, (11) is very difficult to solve in general. In this paper, for expositional purposes, we will restrict our attention to the time-invariant labor allocation equilibrium.

Definition 1 *In a time-invariant labor allocation equilibrium,*

$$l_t^d(z) = l^d(z), \forall z, \; L_t^x = L^x, \forall t. \tag{12}$$

Notice that there is no capital in this model and the productivity shock is i.i.d., and hence the time-invariant condition may not be as restrictive as it seems.[18] Consequently, by (8), $l_t^x(z) = l^x(z)$, $l_t^y(z) = l^y(z)$, $\forall z, \forall t$. This time-invariant condition (12) leads to several results. First, we can characterize the value function.

Proposition 2 *The value function takes a simple log-linear form,*

$$\begin{aligned} V\left(A_t; \overrightarrow{l_t^d}(-z), L_t^x\right) &= V\left(A_t; \overrightarrow{l^d}(-z), L^x\right) \\ &= a_0(z) + a_1 \ln A_t + a_2 \ln\left(1 - l^d(z)\right) + a_3 \ln l^d(z) + a_4 \ln L^x, \end{aligned} \tag{13}$$

where $a_1, ..., a_3 > 0$, $a_4 < 0$, are functions of parameter and other agents' R&D efforts.

The proposition is basically proved by substituting the conjecture into equation (11), and is detailed in the appendix. Given this explicit functional form, it is then straightforward to compute the individual optimal R&D effort (again, all proofs can be found in the appendix):

[18] We, however, cannot prove that it is the only equilibrium in this model.

Lemma 3 *The optimal individual level R&D effort is given by the following expression,*

$$l^d(z) = \frac{\beta(a_3 + a_1(1-p)(1/N))}{\theta_1 + \theta_2 + \beta a_2 + \beta(a_3 + a_1(1-p)(1/N))}. \tag{14}$$

Clearly, $0 < l^d(z) < 1$. Also notice that the value of $l^d(z)$ does not depend on $a_0(z)$, and is hence identical across different agents,

Corollary 4 $l^d(z) = l^d$.

Thus, we do not need to impose, but rather derive symmetry under the time-invariant labor allocation equilibrium. Now, substituting this fact into (10) delivers the following result,

Corollary 5 $\Gamma_b = \Gamma_g l^d < \Gamma_g$ *as* $l^d < 1$.

Now, by (8) and (12), (6) is simplified as

$$y_t(z) = A_t(l^y(z))^{\theta_1}, \forall z, \forall t, \tag{15}$$

with the value of $l^y(z)$ being pinned down by (8). And since we have already solved for the optimal l^d in (14), we know the distribution of the productivity growth, $\gamma_t \equiv A_{t+1}/A_t$, by (9). Thus, to close the model, we only need to dictate the value of the average rent-seeking activities L^x and the government subsidy $S_t(z)$. However, since $l^d(z) = l^d$, by (8), $l^x(z) = l^x$. The rent-seeking activities are also equalized across agents at the equilibrium. Thus, by (4) and (5), we have the following result,

Corollary 6 $L^x = l^x(z)$, $\forall z$, *and* $S_t(z) = 1$, $\forall z$, $\forall t$.

In other words, there is no net subsidy across agents. Thus, everyone consumes his/her own production, $c_t(z) = S_t(z)y_t(z) = y_t(z)$, $\forall z$, $\forall t$. And in that case, the government budget will be trivially balanced,

$$\sum_{z=1}^{N}[(1 - S_t(z))\, y_t(z)] = 0,$$

as the term $(1 - S_t(z)) = 0$, $\forall z$, $\forall t$. Notice however that, even though there is no net transfer of consumption goods across agents, there is a non-trivial amount of labor efforts spent in rent-seeking activities, $l^x(z) = l^x > 0$. Thus, it is analogous to the Prisoner's Dilemma, where every agent is worse off under "the rent-seeking game", although no individual has the incentive to exit from it, given the participation of other agents.

Now, we are ready to study the stationary equilibrium growth path.[19] By restricting our attention to the time-invariant labor allocation equilibrium, we have already shown that labor allocation is identical across agents, and that there is no net transfer of consumption goods across agents. In particular, as $l^d(z) = l^d$, $l^y(z) = l^y$ by (8). Thus, by (15), we deduce that output is identical across agents,

Corollary 7 $y_t(z) = y_t$, *$\forall z$, $\forall t$.*

The aggregate output of this economy is $Y_t \equiv \sum_{z=1}^{N} y_t(z) = N y_t$, where $y_t = A_t (l^y)^{\theta_1}$. And we denote the economic growth rate by γ_t^Y, $\gamma_t^Y \equiv Y_{t+1}/Y_t$. With these definitions, it is then easy to prove the following results:

Proposition 8 *In this economy, (i) the economic growth rate is equal to the productivity growth rate,*

$$\gamma_t^Y = \gamma_t, \ \forall t, \tag{16}$$

(ii) the mean economic growth rate is increasing in R&D effort,

$$E\left(\gamma_t^Y\right) = \Gamma_g \left[p + (1-p)\, l^d\right], \tag{17}$$

(iii) the variance of the economic growth rate is decreasing in R&D effort,

$$Var\left(\gamma_t^Y\right) = p\,(1-p)\left[(\Gamma_g)\left(1 - l^d\right)\right]^2. \tag{18}$$

Equipped with these results, it is easy to see that both mean economic growth and mean technical progress are increasing in R&D efforts, and that the variance of the economic growth rate is decreasing in R&D efforts. Thus, this model reproduces the stylized facts discussed in the stylized facts section:

Proposition 9 *The mean productivity growth and mean economic growth rate are negatively correlated with the variance of the economic growth rate.*

This result begs the question of why R&D effort differs across countries. The appendix shows that (14) can be simplified as

$$l^d = \frac{\beta\,(1-\beta)^{-1}\,(1-p)\,(1/N)}{(\theta_1 + \theta_2) + \beta\,(1-\beta)^{-1}\,(1-p)\,(1/N)}, \tag{19}$$

which implies the following result:

Lemma 10 *The equilibrium R&D effort decreases with the following parameters:*

$$\frac{\partial l^d}{\partial \theta_1} < 0,\ \frac{\partial l^d}{\partial \theta_2} < 0,\ \frac{\partial l^d}{\partial p} < 0,\ \frac{\partial l^d}{\partial N} < 0. \tag{20}$$

[19] See Quah (1996, 1997) for a formal definition.

The intuition is very clear. If the marginal return to either goods production (governed by θ_1) or rent-seeking activities (governed by θ_2) falls, then it is natural to re-allocate the labor input to those activities and hence decrease the R&D effort. If the probability of realizing a good state of nature (p) increases, then the importance of R&D efforts decreases, and so, therefore, will R&D effort. If the number of research agents (N) increases, then it is rational for the individual to "free-ride" on the others and hence the R&D effort will also decrease.

Notice that the parameter θ_2 which is a proxy for the importance of rent-seeking activities in shaping the net transfer of output from the government, can be interpreted as an "institution parameter". And if the institution improves, which means a decline in θ_2, the R&D effort l^d will increase (by (20)). And by (16), (17) and (18), we know that the expected rate of technical progress and expected rate of economic growth will increase, and the variance of the economic growth rate will decrease. And this mechanism exactly match the empirical evidence provided by Tang (2002) and Tang, Groenewold and Leung (2003).

4 Concluding Remarks

Research is typically subsidized. Among others, the subsidy can be in the form of a tax credit, or a subsidy to higher education.[20] And a common justification for such subsidies is that the social return to research exceeds its private counterpart and it is the government's duty to correct this market failure by providing subsidization.[21] This paper provides a supplementary justification: a higher level of technical progress indeed decreases growth volatility, and a reduction of growth volatility is typically interpreted as a "good" thing for society. In other words, this paper claims that technical progress contributes to "output stabilization." This task is achieved by pointing to the stylized facts, that better institutional quality accelerates technical progress, which reduces growth volatility and increases the (average) economic growth rate. With rent-seeking behavior, production activities and R&D efforts all being endogenized, this paper builds a stochastic, endogenous growth model which successfully mimic these stylized facts.

Future research can extend the analysis in several directions. For instance, many simplifications have been made to keep the model tractable, such as abstracting from the accumulation of physical capital and the heterogeneity of agents. Relaxing these assumptions can lead to a much more realistic model and much richer aggregate dynamics through the evolution of the income distribution. Also, the representative agent assumption suppresses the possibility of a liquidity constraint. If the accumulation of physical capital is allowed, and

[20] For instance, see Hanushek and Welch (2005).

[21] See, among others, Jones and Williams (1998, 2000) for a review of the literature and evidence.

yet the fixed cost of starting a business or research is much high than that of rent-seeking activities, liquidity constrained agents may be forced to allocate their talents to the latter, thereby affecting the income distribution and the aggregate dynamics. The transitional dynamics in that situation can be very rich. In addition, the paper stresses the role of technical progress in promoting economic growth, and suppress the importance of human capital.[22] The two factors, however, can be complementary rather than substitute for each other, as demonstrated by Acemoglu (1996, 1997, 1998).[23] Notice that the accumulation of human capital will demand a time input, which is also essential to rent-seeking activities. Thus, introducing human capital accumulation into the current framework will lead to much richer dynamics, which is part of our ongoing research agenda.

In the model, it is assumed that each agent produces, carries out R&D, and also lobbies the government. One can consider a framework in which these activities become choice variables and hence introduce a much richer structure of the economy. One can also follow Eicher and Garcia-Penalosa (2005) to distinguish between "predatory lawyers" and "institution-building lawyers" and to endogenously determine the degree of property right protection and hence the rate of technical progress. Alternatively, one can follow Tse (2004) in explicitly modelling the informational frictions and to provide a much deep micro-structure of the market power and rent-seeking activities. All these possibilities are remained to be explored.

[22] However, there is a large debate on the relative roles of technology and human capital accumulation in driving economic growth which is too large to be reviewed here. See, among others, the exchange between Bils and Klenow (2000) and Hanushek and Kimko (2000), Barro (2001) and Prescott (2002).

[23] See also Leung (1995).

References

[1] Acemoglu, D. (1996), "A microfoundation for social increasing returns in human capital accumulation," *Quarterly Journal of Economics*, 111, 779-804.

[2] Acemoglu, D. (1997), "Training and innovation in an imperfect labor market," *Review of Economic Studies*, 64, 445-464.

[3] Acemoglu, D. (1998), "Why do new technologies complement skills? directed technical change and wage inequality," *Quarterly Journal of Economics*, 113, 1055-1089.

[4] Acemoglu, D.; S. Johnson and J. Robinson (2001), "Colonial origins of comparative development: an empirical investigation," *American Economic Review*, 91, 1369-1401.

[5] Acemoglu, D.; S. Johnson and J. Robinson (2002), "Reversal of Fortune: geography and institutions in the making of the modern world income distribution," *Quarterly Journal of Economics*, 117(4), 1231-94.

[6] Acemoglu, D.; S. Johnson; J. Robinson and Y. Thaicharoen (2003), "Institutional causes, macroeconomic symptoms: volatility, crises and growth," *Journal of Monetary Economics*, 50, 49-123.

[7] Acemoglu, D. and T. Verdier (1998), "Property Rights, Corruption and the Allocation of Talent: A General Equilibrium Approach," *Economic Journal*, 108(450), 1381-1403.

[8] Aghion, P. and G. Saint-Paul (1998), "Uncovering some casual relationships between productivity growth and the structure of economic fluctuations: a tentative survey," *Labour*, 12, 279-303.

[9] Aghion, P. and A. Banerjee (2005), **Volatility and Growth**, Oxford: Oxford University Press.

[10] Angeletos, G.-M. and T. Kollintzas (2000), "Rent seeking/corruption and growth: a simple model," CEPR Discussion Paper 2464.

[11] Backus, D.; P. Kehoe and T. Kehoe (1992), "In Search of Scale Effects in Trade and Growth," *Journal of Economic Theory*, 58, 377-409.

[12] Barro, R. (2001), "Human Capital and Growth," *American Economic Review*, 91, 12-17.

[13] Baumol, W. (1990), "Entrepreneurship: productive, unproductive, and destructive," *Journal of Political Economy*, 98, 893-921.

[14] Bils, M. and P. Klenow (2000), "Does Schooling Cause Growth?" *American Economic Review*, 90(5), 1160-83.

[15] Blackburn, K. and R. Galindev (2003), "Growth, volatility and learning," *Economics Letters*, 79, 417-421.

[16] Buchanan, J.M., R.D. Tollison and G. Tullock (eds.), (1980) **Towards a Theory of the Rent-Seeking Society**, College Station, TX: Texas A&M University Press.

[17] De Hek, P. (1999), "On endogenous growth under uncertainty," *International Economic Review*, 40, 727-744.

[18] Drazen, A. (2000), **Political Economy in Macroeconomics**, Princeton: Princeton University Press.

[19] Easterly, W.; R. King, R. Levine and S. Rebelo, "Policy, Technology Adoption and Growth," in Robert Solow and Luigi Pasinetti (ed.), *Economic Growth and the Structure of Long Term Development*, New York: International Economic Association, 1993.

[20] Eicher, T. and C. Garcia-Penalosa eds (2005) **Institutions for Development and Growth**, Cambridge: MIT Press. forthcoming.

[21] Hanushek, E. and F. Welch eds. (2005), **Handbook of Economics of Education**, New York: North Holland/Elsevier. forthcoming.

[22] Hanushek, E. and D. Kimko (2000), "Schooling, Labor-Force Quality, and the Growth of Nations," *American Economic Review*, 90, 1184-1208.

[23] Jones, C. and J. Williams (1998), "Measuring the Social Return to R&D," *Quarterly Journal of Economics*, 113, 1119-35.

[24] Jones, C. and J. Williams (2000), "Too Much of a Good Thing? The Economics of Investment in R&D," *Journal of Economic Growth*, 5, 65-85.

[25] Kahn, J. (1990), "Moral hazard, imperfect risk-sharing, and the behavior of asset returns," *Journal of Monetary Economics*, 24, 27-44.

[26] Klenow, P. and A. Rodriguez-Clare (2004), "Externality and growth," forthcoming in P. Aghion and S. Durlauf ed., **Handbook of Economic Growth**, Amsterdam: North Holland.

[27] Knack, S. and P. Keefer (1995), "Institutions and economic performance: cross-country tests using alternative measures," *Economics and Politics*, 7, 207-227.

[28] Kwong, K.-S.; L.-C. Chau; F. Lui and L. Qiu (2001), **Industrial Development in Singapore, Taiwan and South Korea**, Singapore: World Scientific.

[29] Lau, S.-H. P. (1999), "I(0) in, integration and cointegration out: time series properties of endogenous growth models," *Journal of Econometrics*, 93, 1-24.

[30] Leung, C. K. Y. (1995), "Educated guesses and income distribution," *Economics Letters*, 48, 173-177.

[31] Leung, C. K. Y. (2001), "Productivity growth, increasing income inequality and social insurance: the case of China?" *Journal of Economic Behavior and Organization*, 46, 395-408.

[32] Leung, C. K. Y. and D. T. Quah (1996), "Convergence, endogenous growth, and productivity disturbances," *Journal of Monetary Economics*, 38, 535-547.

[33] Ljungqvist, L. and T. Sargent (2000), **Recursive Macroeconomic Theory**, Cambridge: MIT Press.

[34] Murphy, K.; A. Shleifer and R. Vishny (1991), "The allocation of talent: implications for growth," *Quarterly Journal of Economics*, 106(2), 503-530.

[35] Persson, T. and G. Tabellini (2000), **Political Economics: Explaining Economic Policy**, Cambridge: MIT Press.

[36] Prescott, E. (2002), "Richard T. Ely Lecture: Prosperity and Depression," *American Economic Review*, 92, 1-15.

[37] Quah, D. T. (1996) "Convergence Empirics across Economies with (Some) Capital Mobility," *Journal of Economic Growth*, 1, 95-124.

[38] Quah, D. T. (1997) "Empirics for Growth and Distribution: Stratification, Polarization, and Convergence Clubs," *Journal of Economic Growth*, 2, 27-59.

[39] Ramey, G. and V. Ramey (1995), "Cross-country evidence on the links between volatility and growth," *American Economic Review*, 85, 1138-1151.

[40] Rebelo, S. (1991), "Long run policy analysis and long-run growth," *Journal of Political Economy*, 99, 500-521.

[41] Rebelo, S. (1998), "On the Determinants of Economic Growth," in **Contemporary Economic Issues: Proceedings of the Eleventh World Congress of the International Economic Association**, London: Macmillan Press, 138-56.

[42] Rogerson, W. (1985), "The first-order approach to principal-agent problems," *Econometrica*, 53, 1357-67.

[43] Stock, J. and M. Watson (1999), "Business Cycle Fluctuations in US Macroeconomic Time Series," in John Taylor, Michael Woodford eds. **Handbook of Macroeconomics. Volume 1A,** New York: North-Holland, 3-64.

[44] Tang, S. H. K. (2002), "The link between growth volatility and technical progress: cross-country evidence," *Economics Letters*, 77, 335-341.

[45] Tang, S. H. K.; N. Groenewold and C. K. Y. Leung (2003), "Institutions, Technical Change and Macroeconomic Volatility, Crises and Growth: A Robust Causation" mimeo., Chinese University of Hong Kong.

[46] Tse, C. Y. (2000), "Monopoly, human capital accumulation and development," *Journal of Development Economics*, 61 (1), 137-174.

[47] Tse, C. Y. (2001), "The distribution of demand, market structure, and investment in technology," *Journal of Economics (Zeitschrift-fur-nationalokonomie)*, 73 (3), 275-297.

[48] Tse, C. Y. (2002), "Monopoly, employment and wages," *Labour Economics*, 9(5), 681-697.

[49] Tse, C. Y. (2004), "Search frictions, market power, and long-run growth," *Journal of Economic Theory,* 116(2), 323-346.

[50] Tullock, G. (1993), **Rent Seeking**, Brookfield: E. Elgar.

[51] Tullock, G. (2003), "The origin rent-seeking concept," *International Journal of Business and Economics*, 2(1), 1-8.

Appendix

(If this appendix is not published, it will be available upon request)

A Proofs

A.1 Proof of (13)

The proposition is basically proved by substituting the conjecture into equation (11), and the left hand side is basically the conjectured functional form, $a_0(z) + a_1 \ln A_t + a_2 \ln\left(1 - l^d(z)\right) + a_3 \ln l^d(z) + a_4 \ln L^x$, and the right hand side is

$$\ln\left(A_t\phi\left(1-l^d(z)\right)^{\theta_1+\theta_2}\left(L^x\right)^{-\theta_2}\right) + \beta p\left(a_0(z) + a_1\ln\left(\Gamma_g A_t\right) + a_2\ln\left(1-l^d(z)\right)\right.$$
$$+a_3\ln l^d(z) + a_4 \ln L^x\big) + \beta(1-p)\left(a_0(z) + a_1\ln\left(\Gamma_g \prod_{z=1}^{N}\left(l^d(z)\right)^{1/N} A_t\right) + a_2\ln\left(1-l^d(z)\right)\right.$$
$$\left.+a_3\ln l^d(z) + a_4\ln L^x\right),$$

which can be re-written as

$$\ln A_t + \ln\phi + (\theta_1+\theta_2)\ln\left(1-l_t^d(z)\right) - \theta_2\ln L^x + \beta\left(a_0(z) + a_2\ln\left(1-l^d(z)\right)\right.$$
$$\left.+a_3\ln l^d(z) + a_4\ln L^x\right) + \beta a_1\ln A_t + \beta a_1 \ln\Gamma_g + \beta(1-p)\,a_1(1/N)\textstyle\sum_{z=1}^{N}\ln l^d(z).$$

Thus, by simply comparing coefficients on different terms, we have

$$a_0(z) = (1-\beta)^{-1}\left\{\ln\phi + \beta a_1\ln\Gamma_g + \beta(1-p)\,a_1(1/N)\textstyle\sum_{j=1,j\neq z}^{N}\ln l^d(j)\right\},$$

and

$$\begin{aligned} a_1 &= (1-\beta)^{-1}, \\ a_2 &= (1-\beta)^{-1}(\theta_1+\theta_2), \\ a_3 &= (1-\beta)^{-2}\beta(1-p)(1/N), \\ a_4 &= (1-\beta)^{-1}(-\theta_2), \end{aligned} \tag{21}$$

and clearly, $a_1, ..., a_3 > 0$, $a_4 < 0$. This confirms the initial conjecture.

A.2 Proof of (14)

The proof is straightforward. We substitute the functional form for V into equation (11), and differentiate with respect to $l^d(z)$, to get

$$\left[(\theta_1+\theta_2)+\beta a_2\right]\frac{1}{1-l^d(z)} = \beta\left[a_3 + \frac{a_1(1-p)}{N}\right]\frac{1}{l^d(z)}.$$

Simply re-arranging terms will yield (14).

A.3 Proof of (16), (17), (18)

By definition, $Y_t \equiv \sum_{z=1}^{N} y_t(z) = N y_t$, where $y_t = A_t\left(l^y\right)^{\theta_1}$, $l^y(z) = l^y$, $\forall z$. Again, by definition, $\gamma_t^Y \equiv Y_{t+1}/Y_t = (N y_{t+1})/(N y_t) = y_{t+1}/y_t = \left(A_{t+1}\left(l^y\right)^{\theta_1}\right)/\left(A_t\left(l^y\right)^{\theta_1}\right) = (A_{t+1})/(A_t) = \gamma_t$, which is (16).

Notice that the economic growth rate is an *i.i.d.* process and hence the conditional mean and unconditional mean coincide and is given by,

$$\begin{aligned} E\left(\gamma_t^Y\right) &= E\left(\gamma_t\right) = p\Gamma_g + (1-p)\,\Gamma_b \\ &= p\Gamma_g + (1-p)\,\Gamma_g l^d, \text{ as } \Gamma_b = \Gamma_g l^d \\ &= \Gamma_g\left[p + (1-p)\,l^d\right], \end{aligned}$$

which is (17).

The variance of the economic growth rate is also easy to calculate,

$$\begin{aligned} Var\left(\gamma_t^Y\right) &= E\left[\gamma_t^Y - E\left(\gamma_t^Y\right)\right]^2 \\ &= p\cdot\left[\Gamma_g - \Gamma_g\left[p + (1-p)\,l^d\right]\right]^2 \\ &\quad + (1-p)\cdot\left[\Gamma_b - \Gamma_g\left[p + (1-p)\,l^d\right]\right]^2 \\ &= p\cdot\left[(\Gamma_g)\,(1-p)\left(1-l^d\right)\right]^2 \\ &\quad + (1-p)\cdot\left[(\Gamma_g)\,(p)\left(1-l^d\right)\right]^2 \\ &= p\,(1-p)\left[(\Gamma_g)\left(1-l^d\right)\right]^2, \end{aligned}$$

which is (18).

A.4 Proof of (19)

The proof is simple. We substitute (21) into (14) to get (19).

A.5 Proof of (20)

Simply differentiate the expression for l^d in (19) with respect to different parameters to deliver (20).

Figure 1: Economic Volatility and Technical Change

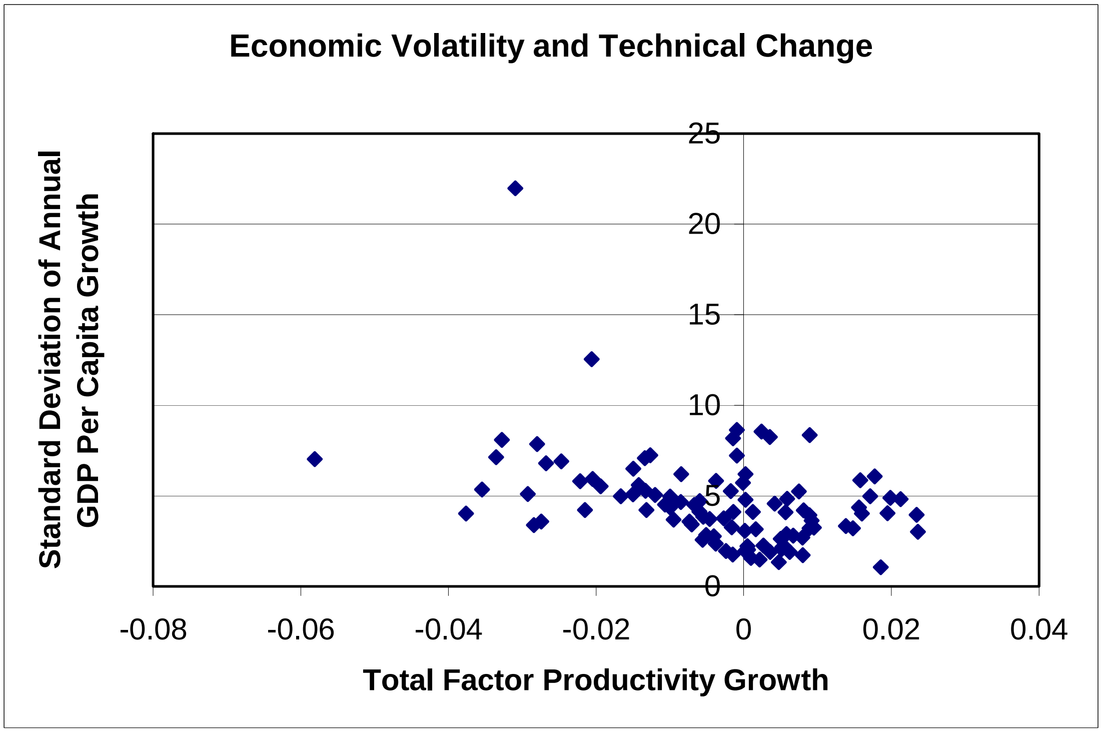

Figure 2: Economic Growth and Technical Change

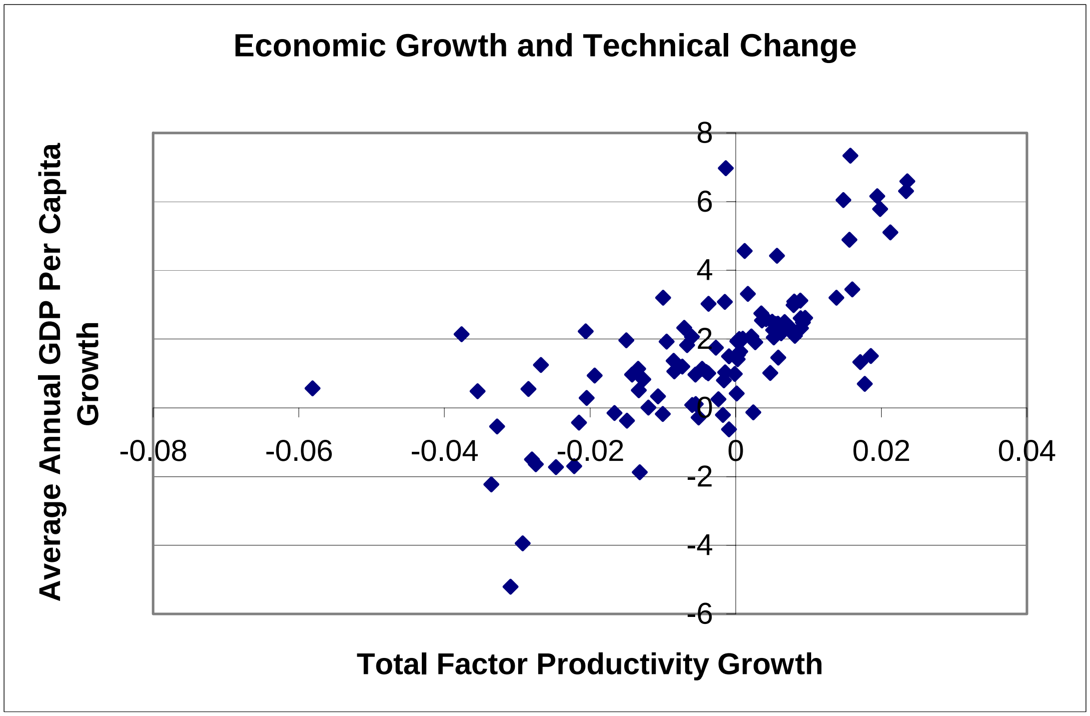

Table 1: Determinants of Macroeconomic Volatility (Robustness to Regional Dummy, Geography, Weather, Human Capital, Openness and Financial Development)

	Equation (1)	Equation (2)	Equation (3)	Equation (4)	Equation (5)	Equation (6)	Equation (7)	Equation (8)	Equation (9)
Dependent variable is standard deviation of annual GDP per capita growth rate									
Initial Constraint on Executive	-0.28* (-1.75)	-0.28 (-1.22)	-0.25 (-1.60)	-0.28 (-1.59)	-0.25 (-1.37)	-0.36 (-1.37)	-0.27* (-1.76)	-0.24 (-1.06)	-0.46 (-1.26)
TFPG	-77.83** (-2.89)	-69.02* (-1.96)	-75.90** (-2.72)	-79.30** (-2.88)	-72.65** (-2.52)	-83.19* (-1.73)	-71.00** (-3.11)	-73.73* (-2.31)	-81.11* (-2.02)
Africa		0.65 (0.61)				0.25 (0.17)			
Asia		(0.49) (0.49)				0.31 (0.19)			
Latin America		0.06 (0.07)				-0.29 (-0.21)			
Latitude			-0.90 (-0.61)			-0.58 (-0.32)			
Coastal Area				-0.08 (-0.11)		0.27 (0.29)			
Mean Temperature					0.05 (1.14)	0.01 (0.06)			
Human Capital							-0.15 (-0.30)		
Openness								-0.39 (-0.28)	
Financial Development									0.98 (0.66)
Observations	60	60	59	58	60	57	50	60	48
R-Square	0.34	0.37	0.34	0.35	0.35	0.38	0.40	0.29	0.24

Notes:

1. Parentheses contain t-ratios. ** and * indicate statistical significance at one or five percent level, respectively, for a one-tailed test.
2. Macroeconomic volatility is measured by the standard deviation of annual real GDP per capita growth rate for the period 1970-98.
3. Initial constraint on executive measures the institutional and other constraints that are placed on presidents and dictators. It has a scale from 1 to 7, with higher scores indicating more constraints. Score of 1 indicates unlimited authority; score of 3 indicates slight to moderate limitations; score of 5 indicates substantial limitations; score of 7 indicates executive parity or subordination. Scores of 2, 4 and 6 indicate intermediate values. We average the scores for 1950, 1960 and 1970 to obtain the average initial constraint. Data are available from *Polity III* dataset compiled by Keith Jaggers and Ted Robert Gurr, 1996, Inter-University Consortium for Political and Social research. This variable is instrumented by the mortality rate of European settler in the ex-colonies. Data are obtained from Acemoglu, Johnson and Robinson (2001).
4. TFPG is total factor productivity growth over the period 1970-90, which is taken from Tang (2002). This TFPG is estimated using a cross-country regression with the growth of output per worker as the dependent variable and a constant and the growth of physical capital stock per worker as the independent variables. TFPG is instrumented by legal system (English, French, German and Scandinavian) and the logarithm of real GDP per capita in 1970. Data for legal system are taken from La Porta, Lopez-de-Silanes and Shleifer (1998) and the website of *CIA- The World Fact Book 2002*.
5. Africa: Dummy variable taking value 1 if a country belongs to Africa, 0 otherwise.
6. Asia: Dummy variable taking value 1 if a country belongs to Asia, 0 otherwise.
7. Latin America: Dummy variable taking value 1 if a country belongs to Latin America or the Caribbean, 0 otherwise.
8. Latitude: Absolute value of the latitude of the country, which is a measure of distance from the equator, scaled to take values between 0 and 1, where 0 is the equator. See La Porta et al. (1999).
9. Coastal area: Proportion of land area within 100 km of the seacoast. From McArthur and Sachs (2001).
10. Mean temperature: 1987 mean annual temperature in degrees Celsius from McArthur and Sachs (2001).
11. Human capital: Natural logarithm of one plus the average years of schooling for the period 1970-90. Data are available from Barro and Lee (1993).
12. Openness: The average ratio of nominal imports plus exports to GDP in Purchasing-Power-Parity US dollars (PPP GDP) for the period 1970-90. Data are available from *Penn World Table Mark 5.6*.
13. Financial development: Natural logarithm of value of credits by financial intermediaries (banks and non-banks) to the private sector divided by GDP. Figures are averages for the period 1970-90 taken from *International Financial Statistics* (IFS) lines 32d/line 99b.