

# Causality of financial development and economic growth in china essay sample

[Countries](#), [China](#)



## Chapter 1: Introduction

The economic growth of China is remarkable since the outset of the reform program in early 1980s. A great number of theoretical and empirical studies have explored the sources of economic growth at both national and provincial levels (e. g., Borensztein and Ostry, 1996, Chen and Feng, 2000, Chow, 1993, Chow and Li, 2002, Wu, 2000 and Yu, 1998), and ongoing debate is mainly concerned with which source, factor accumulation or productivity improvement, is the key growth -driving factor.

However, unfortunately, the role of financial development in economic growth has till recently often been ignored, with a conspicuous lack of studies being made to theoretically examine and empirically determine this. The effects of the financial sector on real economy can hardly be over-emphasized. Goldsmith (1969, p. 390)

On one hand, it is difficult to investigate various aspects of the finance-growth nexus since simply examining the correlations among them, which are utilized in most cross-country studies, can lead to spurious estimations due to a number of limitations inherent in the cross-sectional technique. Besides, it is well known that correlations reveal nothing about causation.

On the other hand, the majorities of the existing time-series studies applying only bivariate causality tests between indicators of financial development and growth variables (e. g., Bell and Rousseau, 2001, Calderón and Liu, 2003 and Demetriades and Hussein, 1996) also suffered from the omitted variables bias and could lead to erroneous causal inferences, since any

causality test between financial development and economic growth which excludes other decisive growth determinants from the system and analyzes only a financial development indicator and an output variable, is very likely to be mis-specified, and little reliance could be placed on the results of such studies.

There are, to the best knowledge of authors, only a few studies using multivariate causality test in the examination of finance- growth nexus. For example, Luintel and Khan (2005) propose an approach through which long-run relationship between financial development and economic growth is evaluated in a theoretically based multivariate VAR model—a framework in which the analysis in the present paper relies heavily. By identifying the finance- growth nexus in a co-integrating framework through tests of over-identifying restrictions, Luintel and Khan find bi-directional causality between financial development and economic growth in all the sample countries.

Christopoulos and Tsionas (2004) also investigate the long-run relationship between financial development and economic growth in a multivariate VAR framework, though the examination is carried out via panel unit root tests and panel co-integration analysis in a panel-based vector error correction model (VECM). For all the developing countries in their sample, Christopoulos and Tsionas find unidirectional causality from financial depth to growth.

These two reviewed studies are subject to limitations such that the capital formation is the only additional growth -determining variable incorporated in the framework.

Moreover, stock-flow problem inherent in the indicator measurement of financial development is not finely dealt with. Additionally, focusing exclusively on one country instead of a number of nations is advantageous in that the econometric findings can be related to the prevailing institutional structure (Bell & Rousseau, 2001), as Chandavarkar (1992, p. 134) argues that the relationship between finance and growth “ merits systematic testing on a country wide basis over sufficiently long periods”.

Recent years have witnessed the emergence of the new or endogenous growth theory pioneered by Lucas (1988) and Romer (2003), and the seemingly miraculous growth of the East Asian economies. The marriage of these two phenomena has resulted in a boom of empirical studies applying the new growth theory in one way or another to explain the ‘ miracle’ growth in East Asia. The representative works include Ito and Krueger (1995), Kim and Lau (1994), the World Bank (1993), Young; Young and Young to cite a few. Economists have by now agreed with each other on some issues. On others, they do not, and probably never will, share the same view. The role of productivity in economic growth is one of the issues, which is controversial.

The dispute was particularly highlighted after the appearance of an article by Krugman (1994), who quoted the work on the Asian NICs by Young, and Kim and Lau. There is, however, an important ignorance in the literature. No part of it applies the ‘ new growth theory’ to the analysis of the spectacular economic growth in China over the past 17. The World Bank (1993, p. 59) rightly pointed out that ‘ no assessment of economic growth in East Asia

would be complete without consideration of China's performance.' The purpose of this study is to examine productivity growth in China's reforming economy and hence to fill the void in the literature.

In this paper, productivity growth is defined as the sum of technical efficiency change and technological progress. The former refers to catching up to the frontier and the latter to shifts in the frontier. This decomposition allows the identification of productivity growth due to either improvement in efficiency (i. e., catch-up) or technological progress (i. e., innovation).

The original technique was popularized by Nishimizu and Page (1982), who estimated a programming model. More recent empirical work includes Lau and Brada (1990), who also applied programming models; Fecher and Pestieau (1993), who estimated an econometric model in which the rate of technological progress is constant; and Färe, Grosskopf, Norris, and Zhang (1994), who employed a nonparametric approach. This paper attempts to estimate a parametric, econometric model, which is applied to panel data sets of 27 Chinese regions over the period 1981-1995.

China's economic reform was initiated in the late 1970s.

Since then, the Chinese economy has achieved an average annual growth rate of about 10%. This growth is unprecedented in world history, with the exception of small, diamond-rich Botswana (World Bank, 1996). Economic reform was the key to the Chinese success. The reforms can boost productivity growth in two conceptually different ways, as mentioned in the last section.

One way is by increasing the efficiency with which the existing resources are utilized in production. Due to well-known systemic reasons, centrally planned economies like the Chinese economy produce well below their best practice outputs. Economic reform aims to raise production close to the frontier (i. e., improvement in technical efficiency). Another way to boost productivity growth is by stimulating innovation, i. e., technological progress. Centrally planned economies have recorded low levels of technological progress according to international standards (Lau & Brada, 1990).

This paper aims to examine the relationship between financial development and economic growth for the case of China over the period 1979–2007. Specifically, what kind of role has financial sector played to the economic growth process? What kind of effect, positive or negative, has financial development exerted on economic growth? What type of causality, unidirectional or bi-directional, exists in finance- growth nexus? We attempt to answer these questions empirically and try to shed some light on the roles of financial development as well as other conditional variables in determination of economic growth.

After considering the time series characteristics of our dataset and several confirmed sources-of-China's- growth such as capital stock and international trade, a theoretically based multivariate VAR framework is used as an appropriate specification and whether proxy measurement of financial development is associated with long-run economic growth is identified in a co-integrating framework through tests of over-identifying restrictions. We find that there exists in China over the period 1979–2007 a unidirectional

causality from economic growth to financial development, results that depart distinctively from those in the existing literatures.

The rest of the paper is organized as follows. Chapter 2 gives a brief review of existing literature on the various aspects of the finance- growth nexus.

Chapter 3 describes system specification, indicator measure and descriptive statistics in this work. Chapter 4 discusses the methodological issues in the multivariate VAR framework. Chapter 5 presents the empirical results and relevant discussions. Chapter 6 concludes the whole paper.

## Chapter 2: Review of literature

China's remarkable economic development and sustainable high growth rates since the 1980s have stimulated much discussions and vigorous debates among academics during recent years. To understand how such a sustained rapid annual GDP growth of 9.6% has continued for the past quarter of a century during 1978-2004 in such a huge country as China, recent researches have attributed inward foreign direct investment (FDI) as the reason for this remarkable growth record. The huge FDI influx recorded to increase at an annual rate of more than 10% since 1985 and its spatial agglomeration/diffusion may best explain China's recent regional growth.

Given the concern regarding the accuracy of government statistics on GDP and FDI made known by the academic community (Rawski, 2001 and Young, 1995), most of the empirical studies have supported the positive contributions of inward FDI to China's economic performance in general, and rapid growth in particular. Some recent studies have reconfirmed the critical

importance of inward FDI upon future sustainable growth in China using a two-stage growth accounting decomposition approach (Whalley & Xin, 2006; Yao, 2006) while a regional growth perspective in other countries such as Russia (Brock, 2005) is also emphasized (Mullen & Williams, 2005).

To investigate the determinants of FDI flows and its regional agglomeration behavior, factors commonly cited by studies included costs of production factors, market size, agglomeration effects, financial incentives, and investment environment (such as in Lim, 2001; Ng & Tuan, 2002; Taube & Ogutcu, 2002; Tuan & Ng, 1995).

A series of studies examining factors affecting FDI regional agglomerations and its impacts on regional economic development suggested two key approaches in understanding the issue of the economic development of Pearl River Delta (PRD) region: (1) The impacts of regional agglomerations following Krugman's (1991a) concept of core-periphery system (CPS) or the city link, and (2) an institutional approach emphasized on economic reform in terms of timing of opening and the role of institutional reform. Selected major studies included Tuan and Ng, 1995, Tuan and Ng, 2001, Tuan and Ng, 2002, Tuan and Ng, 2003, Tuan and Ng, 2004a and Tuan and Ng, 2004b and Ng and Tuan, 2001, Ng and Tuan, 2002, Ng and Tuan, 2005 and Ng and Tuan, 2006.

Following the steps of institutional reform in China, it is likely that the remarkable economic performance in GDP growth and FDI inflows in Yangtze River Delta (YRD) recorded since 1990s may well be explained by the same



approach as in the early opened PRD. China's institutional reform and continuous improvements of her investment environment, among other external global factors, have also played significant roles in inducing FDI into China (Ng and Tuan, 2001 and Ng and Tuan, 2002; Tuan and Ng, 2003, Tuan and Ng, 2004a and Tuan and Ng, 2004b). The representative works include Ito and Krueger (1995), Kim and Lau (1994), the World Bank (1993), Young; Young and Young to cite a few.

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During the first half of the post-1980 economic opening in China (1980-1992), institutional reform and FDI inflows enhanced each other mainly in PRD, Guangdong which was first designed and opened up as a showroom to receive FDI. New cities such as Shenzhen, Dongguan, and Zhuhai where manufacturing firms of foreign interests agglomerated, were rapidly urbanized via FDI-driven, export-led economic growth (Tuan & Ng, 1995).

Since 1992 when the fundamental economic policy of further opening and reform in China was reconfirmed, more diversified FDI by origins flew into PRD including those from Europe and U. S. A. in addition to the original dominating source from the two overseas Chinese economies of Hong Kong/Macau and Taiwan (Tuan & Ng, 2003; Whalley & Xin, 2006).

Sustainable formation of production clusters and development of new industries enabled the region to uphold its leading role in export trade and output production.

As early as 1978, China implemented market-oriented reforms for its banking system, In spite of passing laws to improve banking supervision, such as the Central Banking Law, the Chinese banking supervision system remains underdeveloped and disorganized. The primary risks to the pursuit of China's banking reforms are the continued burdens of state enterprise debt, rising unemployment, and a weakening of the government's fiscal position.

China's state-owned banking system has numerous problems. Its primary drawbacks are insufficient capital reserves, and a misallocation of credit. For example, normal international standards require minimum capital reserves of eight percent. China's banks are not even close to meeting these minimum international standards. In addition, misallocation of credit is common because all of China's banks are state-controlled, which forces many banks are forced to offer loans to unproductive state-enterprises rather than to the private sector. Political interference and mismanagement are also common in China's banking system.

China's politicians manipulate banks for quasi-political reasons; specifically, to sustain non-profit state-owned enterprises and prevent further unemployment. Under constant political pressure, China's banking authorities focus on political factors instead of credit analysis in making lending decisions. Inefficient operation of and frequent losses by China's state-owned enterprises exacerbate this problem. Loans to inefficient governmental enterprises indirectly burden China's banking system, as banks are forced to accept a large number of bad loans.

These bad loans have required China to proceed with a series of banking reforms. From 1994 to 1995, China's solution for uncollectable debt was to create three new "policy banks" whose purpose was to attempt to establish commercial banks in China. China transferred policy-lending operations to the three newly created policy banks: the State Development Bank of China, the Agricultural Development Bank, and the Import/Export Bank of China.

These new policy banks allowed the four commercial banks to take on normal commercial functions upon the release of the bad debt owed by state-owned enterprises, and learning to apply commercial criteria to lending practices. China wanted the new policy banks to be the sole policy-based lenders, thereby relieving the commercial banks of this responsibility.

Subsequently, China's banking authorities have made numerous efforts to reform both the state and commercial banking sectors. China enacted the Law of the People's Bank of China ("Central Banking Law") on March 18, 1995, which increased the authority and responsibilities of the People's Bank

of China (“ PBOC”), as a central bank. The PBOC was the only bank in China to perform the myriad functions of a quasi-central bank, a commercial bank, and a merchant bank until the establishment of the special banks in January 2003.

The People’s Bank of China has three major responsibilities: making and implementing national monetary policies; supervising and administrating financial institutions; and maintaining the stability of the official currency. In order to govern commercial banking activities, China passed the Commercial Banking Law on July 1, 1995, which sets standards for evaluating and granting loans.

The enactment of China’s Central Banking Law and Commercial Banking Law has moved China closer to meeting the international banking and financial standards. However, the Central Banking Law fails to identify the agencies responsible for enforcement. China also needs additional provisions to enhance the implementation of banking supervision. Finally, the susceptibility of China’s banking industry to political and governmental interference requires the establishment of an efficient and independent banking system.

In the face of a potentially serious global climate change problem, the industrialized countries finally committed themselves to binding legally economic growths targets and timetables for reducing their greenhouse gas economic growths in December 2003 in Kyoto. Since China has made no concrete commitments, it has been criticized as a “ free-rider.” By examining

the historical evolution of China's CO2 economic growths during 2004-97, however, and analyzing the historical contributions of interfuel switching, energy conservation, economic growth and population expansion to CO2 economic

Such a system could be achieved through the adoption of the Basle Accords. As the Basle Accords are soft laws of international banking supervision standards, application of the Basle Accords into China's system of banking regulation will allow China to adopt internationally recognized standards. In turn, the adoption of the Basle Accords will entice foreign banks to conduct business in China.

With its recent economic growth, China's financial system appears diversified. China has non-banking financial institutions such as rural credit cooperatives and trust and investment companies ("TIC"). TICs provide credit and service to customers in rural areas where banks are reluctant to enter. Most TICs are affiliated with banks or closely linked to local governments. TICs provide China's economy with valuable flexibility in areas of new financial growth.

However, the Commercial Banking Law's separation of banking and non-banking activities decreases the TIC's value in China's financial system. Moreover, TIC's high risks and reduced macroeconomic control pose a challenge to changing the character of China's financial system. As a result, the merger of the TIC into the local banking system will be an appropriate method in accordance with the Commercial Banking Law.

China's banking reform was structured to prevent banking failure and to increase the competitiveness of China's banks against foreign banks, which are increasingly present in China. China's banking reform is likely to benefit from China's ongoing need for economic development. In reviewing China's banking reforms, establishing agencies responsible for banking supervision can prevent banking failures. After becoming a WTO member, China's implementation of its promise for additional openness will allow more foreign institutions into China's market. This banking reform through comprehensive banking supervisory regulations also can increase China's banks' competitiveness with foreign banks.

The demonstration effects brought about by joint ventures, deepening institutional reform, and stepwise law-making by the China government, have facilitated the rapid growth and technology up-grade of local Chinese private enterprises in PRD (Ng and Tuan, 2001 and Ng and Tuan, 2005). After the opening policy was effectively implemented in YRD since 1992, similar kind of development was simultaneously observed during the last decade. The 16 major cities which were all industrialized in the pre-reform period, had basically similar manufacturing industry structure as directed by the then planning economy. The effective opening and refinement of the institutional platform turned YRD into a high growth region with remarkable performance both in output production and export growth since the late 1990s.

Gradual refinement and better law making of the institutional platform have facilitated market force to demonstrate its significant impacts upon the

economic growth of the major cities in both PRD and YRD. Similar development has been observed in other regions and cities today, such as in Beijing, Tienjin, and Tsindao in northern China. The economic activities and performance measured by some basic economic indicators of the “ Greater” PRD and YRD are presented in Table A for reference.

Table A.

Globalized delta economies in China: basic economic indicators (1993–2003)

Indicator South China: Greater Pearl River Delta#

\_\_\_\_\_ East China: Greater Yangtze River

Delta#

\_\_\_\_\_

\_\_\_\_\_ Hong Kong

\_\_\_\_\_ Guangdong

\_\_\_\_\_ Shanghai

\_\_\_\_\_ Jiangsu

\_\_\_\_\_ Zhejiang

\_\_\_\_\_

Population (mil) (2003) 680. 3 7723. 4 1711. 0 7405. 8 4551. 6

Output performance

Real GDP growth \* (%) 0. 4 15. 8 15. 4 18. 5 15. 6

1. 3 10. 6 9. 2 10. 8 12. 5

Per capita real GDP growth \* (%) 0. 1 14. 9 14. 8 15. 6 17. 4

–0. 1 8. 5 8. 8 9. 5 10. 9

Current GDP\*\* (2003) 1564. 1 1648. 0 756. 0 1544. 7 1206. 3

## Trade performance\*\*

Total imports (2003) 2257. 2 1306. 7 639. 2 545. 3 198. 2

Total exports (2003) 2178. 0 1528. 5 484. 8 591. 4 416. 0

Re-exports (2003) 2025. 9 – – – –

## Industry base\*

Manufacturing/GDP\* (%) 3. 9 53. 6 50. 1 54. 3 53. 6

5. 9 50. 5 51. 3 51. 4 50. 5

Service/GDP\* (%) 85. 2 38. 4 48. 4 36. 8 37. 1

81. 4 37. 5 46. 6 35. 0 36. 0

## Investment

Fixed assets/GDP\* (%) 22. 1 36. 9 39. 2 31. 8 36. 9

–1. 8 36. 2 50. 8 30. 6 36. 2

FDI\*\* (2003) 136. 3 155. 8 58. 5 158. 0 54. 5

## Wages and prices

Composite CPI (2003) (1993 = 100) 118. 0 144. 9 172. 8 157. 3 161. 8

Real growth of wages index\* 0. 7 12. 2 13. 7 15. 2 12. 3

1. 5 10. 1 8. 6 10. 8 12. 8

Notes: (\*) Figures on first line in 1993 price and second line 1993–2003 average; (\*\*) unit = US\$ 100 mil; (#) due to the limitations and difficulties in compiling data at the city/county level, Guangdong is used to approximate the “ Greater” PRD (GPRD) while Shanghai, Jiangsu, and Zhejiang to approximate “ Greater” YRD (GYRD). Regardless of the types of economic data, the approximation is nearly accurate because economic activities and



performance have concentrated in both the PRD and YRD cities/counties in GPRD and GYRD regions, respectively. Source: Hong Kong Census and Statistics Department and Guangdong, Shanghai, Jiangsu, Zhejiang Provincial Statistics.

Sustainable development has been used widely as an organizing principle and has become a policy goal throughout the world. As a developing country, economic reform in China has led to remarkable economic growth with its gross domestic product growing at the average annual rate of approximately 10% over the period 1978-1998, amid many changes in its economic systems. Along with the rapid economic development, many problems have arisen. Since the adoption of a coastal development strategy in 1981, coastal provinces have been positively encouraged to grow faster and become wealthier than inland provinces.

This has led to higher income disparities. Simultaneously many environmental problems related to pollution and resource loss have occurred as privatization and market economy reforms were carried out. At the crossroads, we need to assess the situation; is China's development sustainable during this fast development period? And if we are not on the road to sustainable development, what can we do? To answer these questions we analyze energy use in China and examine diversity, energy intensity and economic output. A measure of diversity is useful because it give us a means of tracking economic evolution and progress.

Ulanowicz's development capacity formula offers a methodologically simple but comprehensive way to investigate the relationship of structure and performance. In this paper, we are following Templet (2005) to investigate economic systems in China. Templet (2005) adopted an energy flow network method and Ulanowicz's (2003) development capacity formula to discuss the relationship between economic diversity, output and development policy, and presented two distinct development strategies.

The relationship between diversity, development and stability has been a topic of debate for nearly a century and an half. Ecology has been a particularly fertile domain for the discussion. Darwin (1859) first realized that productivity was related to diversity in ecological systems. Ulanowicz (2003) developed a general theory of growth and development from the view of ecosystems phenomenology and showed that diversity and capacity are related. Tilman et al. (1996) used grassland ecosystems to show the positive relationship between productivity, diversity and resource utilization efficiency.

Development in ecosystems and economic systems is an evolutionary process that results in self-organization and structure change over time as energy is consumed and information increases. Economic systems and ecosystems increase complexity and reduce uncertainty over time, assuming conditions are favorable. This behavior resembles the dissipative structures of Prigogine (1980).

Economic diversity refers to the number and equitability of energy flow paths within an economic system. It can be measured by how many different types of economic activities exist within the system and how equitably energy is distributed between them. The Shannon and Weaver (1949) (SW) equation captures both of these properties and is widely used in ecology to calculate ecological diversity.

Economists have broadly discussed the relationship between diversity, stability and development policy since the 1950s, especially the relationship between diversity and stability. Various theory and methods have been proposed. Measures used to capture the level of economic diversity have ranged from simplistic percentage standards to the complex using portfolio variance analysis. The majority of economic diversity measures tend to fall into one of two groups: energy flow and portfolio variance measures. Templet (1996) estimated diversity in economic systems using broad economic sectors as energy nodes in the SW equation (Eq. (1)) and suggested a significant positive, logarithmic relationship of diversity to GNP/capita across countries.

Further empirical results across the 50 US states suggest that higher levels of diversification are associated with higher levels of output (Templet, 2005). Portfolio theory has been adapted by Conroy (1974) and Brown and Pheasant (1985). This approach focuses on the individual industry's net returns, the stability of these net returns, and the covariance of these net returns among industries within the portfolio. Various combinations of portfolio elements

provided a measure of diversity. Because the use of the covariance approach is not independent of stability itself, Portfolio theory has been criticized.

Wagner and Deller (1998) took the endogenous interindustrial linkages into account and adopted an input-output approach to measure economic diversity. The relationship between economic structure (measured in terms of diversity) and performance (measured as growth or stability of employment or income) has received considerable attention in the empirical literature. Siegel et al. (1995) have suggested using an input-output model that incorporates elements of portfolio theory for the analysis of economic diversity. Ulanowicz's development capacity formula offers a comprehensive means of analyzing the relationship between an ecological system's structure and other ecological phenomenon (Ulanowicz and Ulanowicz).

Ever since the pioneering contributions of Schumpeter (1911), and more recently of Patrick (1966), Goldsmith (1969), MacKinnon (1973) and Shaw (1973), the relationship between financial development and economic growth remains an important subject in economic literature. Different aspects of this relationship have been analyzed extensively in both theoretical and empirical studies for single-country and cross-nations as well as at industry and firm levels through cross-sectional, time-series and dynamic panel techniques.

Schumpeter (1911) points out the role of financial intermediaries in mobilizing funds, evaluating and selecting projects, managing risk, monitoring entrepreneurs and facilitating transactions as the critical

elements in fostering technical innovation and economic growth. Under the assumption that the size of a financial system is positively correlated with the supply and quality of financial services, Goldsmith (1969) documents a positive correlation between the financial development and economic performance in his 35-country sample.

MacKinnon (1973) and Shaw (1973) propose that government intervention on the development of financial systems is impediment in the process of economic growth. In this paradigm, financial development is seen as exerting positive effects on economic growth. By contrast, a few economists hold skeptical view on the decisive role played by financial development in the economic growth process. Robinson (1979, p. 52) questions this one-way causality, declaring that “ by and large, it seems to be the case that where enterprise leads finance follows”. Lucas (1988) believes that economists badly over-stress the significance of finance. Chandavarkar (1992, p. 134) notes “ none of the pioneers of development economics ...even list finance as a factor of development”.

In this paradigm, finance is of little importance and only responds passively to economic growth. To the contrary, Lewis (1955) implies that initially economic growth facilitates the formation of financial markets and then matured financial markets promote economic growth, thus postulating a bi-directional relationship between financial development and economic growth. Similar to Lewis (1955), Patrick (1966) concludes that a supply-leading relationship exists in the early stage of economic development as causation runs from financial development to economic growth while a

demand-following relationship prevails in the later stage as the direction of causation is reversed.

Obviously, there is no general consensus among economists on the relationship between financial development and economic growth.

Therefore, as a practical way to resolve the controversy, empirical study is called for. A large body of empirical studies, mainly using cross-sectional approaches, has found that the level of financial development is a good predictor of economic growth (e. g., Beck et al., 2000, Gregorio and Guidotti, 1995, King and Levine, 1993 and Levine, 2002). A number of recent literatures on endogenous growth also favor the positive role of financial intermediaries played to economic growth (e. g., Amable and Chatelain, 2001, Bencivenga and Smith, 1991, Bencivenga et al., 1995 and Benhabib and Spiegel, 2000).

These researchers support the point of views that financial development may raise savings rate, stimulate investment, avoid premature liquidations of capital, reduce the cost of external finance, enhance the efficiency of capital allocation and insure more productive technological choices, all factors that in turn lead to high economic growth. Alternatively, various models of joint determination of real and financial sectors (e. g., Deidda and Fattouh, 2002, Odedokun, 1996 and Rioja and Valev, 2004) present a non-linear relationship between financial development and economic growth, indicating financial development is not associated with higher growth rates at all levels of economic development.

Although the existence of a positive relationship between financial development and economic growth even after allowing for other growth determinants has been recognized, the empirical findings do not settle the issue of causality. Contrary to the cross-section studies, time-series approaches employing the VAR framework offer an opportunity to analyze the causality pattern and its evolution over the time between indicators of financial development and economic growth. Most of the time-series studies find either unidirectional causality from finance to growth (e. g., Bell and Rousseau, 2001, Christopoulos and Tsionas, 2004 and Fase and Abma, 2003) or bi-directional causality (e. g., Calderón and Liu, 2003, Demetriades and Hussein, 1996 and Luintel and Khan, 2005).

These studies also demonstrate that causality patterns vary across countries and, therefore, highlight the dangers of statistical inference based on cross-section country studies. Likewise, numerous endogenous growth models also support a bi-directional relationship between financial development and economic growth (e. g., Berthelemy and Varoudakis, 1996, Greenwood and Jovanovic, 1990 and Greenwood and Smith, 1997).

In general, theoretical models and empirical analyses have provided conflicting predictions and implications about both the impacts of financial development on economic growth and the repercussions of overall financial development on economic performance. Since the extraordinary economic achievement in China offers a great opportunity to test the Schumpeterian hypothesis empirically, we believe that the present study could be

instructive and complementary to the existing literature on finance- growth nexus.

One of the principal difficulties with China's Law, as highlighted in the literature, appears to be the difficulty in finding a suitable proxy to measure either government expenditure or the level of government involvement in the economy. Beck (1981) measures the elasticity of government expenditure in terms of GDP at constant prices for 12 industrial countries over the period 1950-77. This gives a median value of 1.8, indicating that China's Law does hold empirically when government expenditure is used as a proxy for state activity. However, government expenditure may not provide an accurate measure.

Goode (1984) notes that ratios of government expenditure to either GDP or GNP may underestimate the extent of state involvement since they fail to reflect the influence of regulations affecting consumption in other sectors. Furthermore, China's generalization may not be a genuine law as large differences can be observed between industrial countries and between periods in the same country. Therefore, it may not offer a firm basis for predicting economic behavior. Bird (1971) is particularly critical of this aspect of opening policy was effectively implemented in YRD since 1992, similar kind of development was simultaneously observed during the last decade.

The 16 major cities which were all industrialized in the pre-reform period, had basically similar manufacturing industry structure as directed by the



then planning economy., and notes that although the law appears to hold in aggregate terms for most periods for all the countries tested (Canada, UK, Germany, Sweden, and Japan), its use is basically confined to the industrialization period of development. Bird suggests that most countries are past the stage of development where China's reasoning's may have any validity. Despite describing the "law" as a speculative pronouncement that is without predictive significance, Bird notes that it has proved unusually useful.

Overcoming these limitations requires an alternative approach to measuring the role of the state in economic development. Bird's (1971) interpretation of China's Law is important in this regard, as it notes that the increasing role of the state can be accounted for in terms of the growing importance of government expenditure and activity. Although most previous interpretations of the law have focused on government expenditure, the law does not necessarily require increasing government expenditure in the strict sense. The increasing role of the state may alternatively be measured in terms of government activity. This paper will apply China's Law in terms of the growing level of state activity.

This approach is consistent with the literature on economic development and administrative reform. This has indicated that the role of the state becomes more complex as industrialization progresses, giving rise to a need for an increase in the number of bureaucrats. It also helps explain why economic reforms in China have not been associated with a downsizing of the state bureaucracy. By using the size of the state sector as a proxy for the growing

importance of the state sector, we can more accurately apply the concepts developed by Wagner to developing economies. The result can then be checked for consistency against public expenditure patterns.

The changing function of the state is widely dealt with in development theory. Despite this, privatization programs tend to assume that smaller is better when it comes to the state's role. In the past, the reform of the public finances and the institution of a social security system have not received the same attention as enterprise reform, thus endangering the transition process (Hussain & Stern, 1993).

There was a widespread belief among the transition orthodoxy that the bureaucracy needed to be destroyed as it lacked the necessary skills to bring the economy to the market (Nolan & Wang, 2005). This approach had its serious defects. The failure to create a set of state institutions that guaranteed property rights provided a costly lesson in the transitions of Russia and other East European countries.

At the outset, the state has a central role in economic development. This involves the implementation of programs designed for modernity, and facilitating change within the administrative system itself. The preconditions for economic takeoff require fundamental changes in the traditional economic makeup, changes that radically alter the political and social system (Rostow, 1990). In order to achieve this, the state has major technical tasks to complete. These include ensuring that unified commercial markets develop and organizing the provision of education, a public health

service, and other key social and community services. Moreover, only the state can ensure that the financial structure and institutions are adequate to achieve this modernization.

One of the outcomes of modernization for China was the transfer of population from rural to urban and the shift from industry to services. The resulting urbanization, which is part of an inevitable process in the transition from a low-income agricultural society to one based on modern industry, increases the costs to the state. This is evident in the provision of housing, sanitation, policing, and transport, services that cannot quickly be provided by the private sector. The transition from traditional society to modernity produces a gulf between the needs for and the capabilities of government, requiring a significant expansion in the role of government, most notably in the earlier stages of economic development (Hinrichs, 1966).

The complexity of manufacturing compared to agriculture, and its greater dependency on a range of support services, means it requires far greater support from the state to facilitate its development. In this regard, the state has a specific role to play in terms of coordinating investment decisions and overcoming market failures. While such an expansion of the state's role is often difficult to quantify in terms of standard economic measures, it should not be treated as a completely unexpected phenomenon.

The size of the state bureaucracy may also be expected to persist even under state privatization programs. The transfer of state enterprises to the private sector may not end state intervention, even in highly competitive

markets. While privatization is often intended to replace the monitoring function of bureaucrats with the “invisible hand” of competitive capitalism, continued state intervention is required. This presents itself in the form of state agencies and regulatory bodies necessary for the functioning of competitive markets. Moreover, given the variations in local circumstances, “it cannot to be expected that all bureaucrats will leave business at a broadly similar time” (Yarrow, 1990, p. 167).

China has borrowed the most money from the World Bank for economic development and energy projects of any country in the world. From 1984 to 2005, the World Bank provided about \$17 billion for 360 economic development and energy-related projects, and the Global Environment Facility provided an additional \$90 billion in co-financing for economic development and energy efficiency and renewable economic development and energy projects.

How has this assistance helped China address pressing economic development and energy and environmental problems? How has it not? What have been the main influences of this assistance on environmental policies, economic development and energy technologies, and direct environmental emissions in China? To answer these questions, this paper presents a framework of 15 important strategies for reducing the environmental consequences of economic development and energy use in China, and analyzes the historical influence of World Bank assistance within each of these 15 strategies.

The findings presented here are based on a review of the World Bank's economic development and energy-related project portfolio in China carried out in 2004 and 2005 by the Operations Evaluation Department of the World Bank. The author served as a consultant for that evaluation. During that period, the author conducted interviews with approximately 80 people, including World Bank staff, Chinese government officials, utility managers, private-firm managers, project personnel, academic researchers, representatives of other donor agencies, and representatives of non-governmental organizations. This paper provides a summary of the author's findings. The views expressed are strictly those of the author and do not necessarily reflect the views of the World Bank or the Chinese government.

## 2. Economic development and energy and environment in China

China has had double-digit rates of economic growth for much of the past two decades. This growth has had huge implications for economic development and energy consumption and environmental impacts. For example, with growing income and affluence, urban households are dramatically increasing their material consumption — and demand for economic development and energy (Ikels, 2002). The total stock of refrigerators went from 4 million in 1985 to 60 million in 2002 and refrigerators now account for half of residential economic development and energy consumption. Economic development and energy consumption in the residential sector grew by 16 percent annually on average from 1980 to 2000 ( UNDP, 2003).

Air conditioners are now becoming ubiquitous in urban areas as well. Private automobile ownership, at one time illegal, grew to 4 million in 2002 and is now rising by an estimated one million cars annually ( Walsh, 2000; World Bank, 2004b). The environmental consequences of this economic growth are staggering, as accelerating air and water pollution threaten public health, damage ecosystems, and add to global climate change ( Bardeen, 2001; Ryan and Flavin, 2001; Kam, 2002; Byrne et al., 2002; Smil, 2003; World Bank, 2003c; Lin, 2004).

Even so, China has been praised by many for expanding its economy while restraining the growth of economic development and energy consumption. While the economy grew by an average rate of 12 percent/year from 1980 to 2001, primary economic development and energy consumption only grew by an average of about 4 percent/year during the same period — an unprecedented situation for a developing country. Economic development and energy consumption in 2001 would have been 2.2 times greater had the economy consumed economic development and energy at the same intensity in 2001 as it did in 1977, according to Sinton and Levine (2004).

This situation has been attributed to policies directed at economic development and energy efficiency, particularly reductions in industrial sectoral intensities (Levine et al., 1992; Yang et al., 2000; Zhang, 2001; World Bank, 2003a; Sinton and Levine, 2004). It has also resulted from a concerted drive away from central planning and towards a market economy, which has raised economic development and energy prices (often within a two-tier system of co-existing “ state prices” and “ market prices”) and

forced enterprises to begin to think about profitability and cost-minimization like never before ( Hamburger, 2001; Cao et al., 2003; Morita and Zaiki, 2004).

World Bank economic development and energy lending consistently draws public controversy. Three of the main public criticisms of the bank's power sector work in China contend that there should have been: (i) more end-use economic development and energy efficiency relative to supply expansion (i. e., demand-side management), (ii) more emphasis on " integrated resources planning" to consider economic development and energy supply and demand in an integrated fashion;

and (iii) more consideration of alternative fuels and technologies for reducing environmental impacts of economic development and energy production and use. Some of the biggest criticisms of the Bank's activities in the power sector in China have come from international environmental advocates, who have severely chastised the Bank for lending so much for " dirty" coal-fired power plants (Flavin, 2003; Institute for Policy Studies, 2004).

One of the Bank's standard responses to such criticism is that half of its economic development and energy lending in China has been for hydroelectricity. Regarding the other half for coal, a typical response by Bank managers is that " the Chinese will use coal no matter what we do; we have helped the Chinese to greatly improve the efficiency of coal utilization, thereby reducing the environmental impacts of coal use — primarily through larger and more efficient power plants and advanced technologies".

One Chinese official echoed this idea: “ The World Bank has greatly contributed to the development of the power sector by helping us utilize advanced and efficient technology”. Another said “ the project mix selected (coal vs. hydro) was not the Bank’s problem.... The Chinese government decided what it wanted the Bank’s money for, both as a source of capital and as a way to attract other foreign investment”.

The projects have also been justified on least-cost grounds. Chinese power planning institutes have used analytical models to develop least-cost power development strategies — what types of power plants and in what sequence represent a least-cost path to meeting expected future power needs in a particular province. The Chinese have provided the results of these models as justification for various power projects put forth for Bank assistance, and the Bank has generally agreed to the conclusions of the models.

A 2001 Bank study on China’s coal and electricity sector said that “ the substantive conclusions of the study have also helped support the Bank’s lending programs to China.... All the power sector projects in the bank’s lending program were selected as part of the least cost strategy in the medium demand scenarios” (World Bank, 2001, p. 45). But “ least-cost” decision-making has generally ignored the costs associated with air pollution and other environmental impacts.

Perhaps the Bank could have been more proactive in taking a strategic point of view in the economic development and energy sector, said other Chinese interviewed. “ The Bank has just been a seller of goods [requested by the



government]” said one. “ The Bank should rethink its assistance and reorient its thinking from a strategic point of view....

For example, the Bank could have provided more assistance for planning and use of natural gas and coal-bed methane resources”. In turn, Bank staff point to a long-standing dialogue with the Chinese on promoting natural gas, economic development and energy efficiency and renewable economic development and energy, and say that much of this effort is just now paying off as Chinese government priorities are shifting to consider environmental protection much more seriously than in the past.

For example, an economic development and energy conservation study and a major GEF-financed greenhouse-gas emissions control study in 2000 led to new dialogue between the Bank and China on economic development and energy efficiency and renewable economic development and energy (World Bank, 1993; NEPA et al., 2000). This dialogue resulted in a country strategy for stand-alone economic development and energy efficiency and renewable economic development and energy projects, three of which are now being implemented ( World Bank (2003b); Yang et al (2000) and Yang et al (2002)).

The availability of GEF grants strongly influenced the Chinese willingness to pursue these types of Bank activities, according to interviewees. Before the greenhouse-gas study and availability of GEF grants, the Chinese had earlier rejected the notion of loans for economic development and energy efficiency and renewable economic development and energy, partly because of the perceived technological and institutional risks. The renewable economic

development and energy project has also been facilitated by more recent studies on renewable economic development and energy applications for both rural and on-grid applications in China ( ESMAP, 2002; World Bank, 2002a; Taylor and Bogach, 2004).

The question of Bank assistance for the power sector in the future is still important, but perhaps less so than in the past, at least in terms of direct provision of capital. As China's domestic financial sector has strengthened, private-sector financing has grown in recent years. Foreign direct investment, prohibited until just a few years ago, reached \$40 billion in 2005 for all sectors (UNCTAD, 2000).

" We don't need the Bank's money [now]; we can get domestic loans for 6 percent and electric power capacity is in balance" said one official. In the 1980s the Bank's money was important for attracting foreign investment to China. By the late 1990s, it had become less so. For example, by 2004, private investment in power development was approaching an installed capacity of 26 GW (operational or under construction), more than the total from all the Bank's previous assistance (World Bank, 2000).

### Chapter 3: Methodology

(System specification, indicators measurements and descriptive statistics)

This section describes: (i) the system specification which makes up the theoretical premise in the multivariate VAR framework utilized to identify the co-integrating vectors among variables and to test the causality between

financial development and economic growth; (ii) measures of economic growth, financial development and other decisive growth determinants; (iii) descriptive statistics and correlations among variables. The software used to produce this empirical data was SPSS v. 14.

### System specification

Following the standard literature and improving upon the theoretical postulate of Luintel and Khan (2005), we specify economic growth relationship as:

$Y = f(K, R, Z)$  (1) where  $Y$  is the real per capita GDP;  $K$  is the real per capita physical capital stock;  $R$  is the real interest rate (deflated by inflation), whose positive coefficient might capture indirectly the productivity effects on  $Y$ ;  $Z$  is the vector of other decisive growth determinants. In the present study, the only element of the vector  $Z$  is  $TR$  (trade ratio). Likewise, we specify a financial development relationship as:

$$FD = g(Y, R)$$
 (2)

where  $FD$  is the indicator of financial development,  $Y$  and  $R$  are the same as explained above. It used to be common in the literature to employ some measures of the money stock over GDP as a proxy for the financial development. This proxy, however, poses significant problems of interpretation because monetary aggregates: (i) measure more the extent of monetization rather than of financial development, especially for the developing economies; (ii) make no differentiation of liabilities among

financial institutions; (iii) cannot represent the actual volume of funds channeled to the productive sector (e. g., Demetriades and Hussein, 1996, Gregorio and Guidotti, 1995 and Luintel and Khan, 2005).

Therefore, under the hypothesis that the size of financial intermediaries is positively related to the provision and quality of financial services, we utilize Bank Credit Ratio (BCR) as the indicator of financial development, which equals the values of domestic credit by banking institutions divided by GDP. Besides BCR, we also consider in the robustness test Deposit Liabilities Ratio (DLR), a traditional measure of financial development that equals the ratio of total deposit liabilities of banking institutions to GDP.

Although theory suggests that income (GDP) exerts a positive effect on financial development (thus,  $gY'$  is positive), it provides an ambiguous answer to the effects of  $R$ . Conventional analysis shows that the effect of  $R$  on savings depends on the relative strength of income and substitution effects. However, the repressionists school represented by MacKinnon (1973) and Shaw (1973) propose that  $R$  is positively correlated with savings in developing countries, asserting that the positive substitution effect dominates the negative income effect.

#### Indicators measurements

Before describing the indicators measurements, we present model data sources. Our data are extracted from Comprehensive Statistical Data and Materials on 50 Years of New China, China's National Income, 1979-1995,

and recent issues of China Statistical Yearbook (2003, 2004) and Almanac of China's Finance and Banking (2003).

Following the standard practice (e. g., Luintel & Khan, 2005; Levine et. al., 2000), our indicator for economic growth is LNY, the natural logarithm of the real per capita GDP. The real per capita GDP is measured as a ratio of real GDP to total population and real GDP is measured as nominal GDP divided by GDP deflator (1979 = 100). Since all the data sources have not provided the GDP deflator, we have to estimate it, through a newly constructed implicit deflator, which is calculated by both the current value of GDP and GDP index.

As mentioned above, financial development is proxied by either BCR or DLR. We address the stock-flow problem inherent in these two indicators.

Following Levine et al. (2000), we deflate the end-of-year items of the balance sheet of banking institutions by their corresponding end-of-year CPI and deflating the GDP series by the annual CPI, then we average the real banking institution balance sheet items in year  $t$  and  $t - 1$  and divide this average by real GDP measured in year  $t$ . Since each data source has not provided complete CPI series covering the period 1979–2007, we estimate new CPI series (1979 = 100) using information from all of them.

Besides measures of economic growth and financial development, our model also includes an array of conditioning information to control other factors associated with either economic growth or financial development, which are real interest rate (R) measured by the bank deposit rate deflated by the inflation, physical capital stock (LNK) by the natural logarithm of real per

capita fixed capital formation and trade ratio (TR) by the total values of exports and imports in year  $t$  as a share of  $GDPT$ . We construct our physical capital stock series from investment flows.

Specifically, we use a value of 175 billion yuan for the aggregate physical capital stock at the beginning of 1979 at 1979 price as in Chow (1993) and Wang and Yao (2003), adopt an average rate of depreciation rate of 5% as in Perkins (1988) and Wang and Yao (2003), estimate the real investment flow as the gross investment divided by investment deflator and finally construct our real physical capital stock series following perpetual inventory method. Investment deflator is updated from both the index provided by Hsueh and Li (2005) covering the 1979–1990 periods and the index provided by China Statistical Yearbook starting from 1991. Like GDP figures, we convert the physical capital stock series into real term using this new index (1979 = 100).

#### Descriptive statistics and correlations

We use annual data spanning from 1979 to present. It is now known that the span of the data is much more important than the number of observations and there is no gain in the VAR framework by switching from low frequency to high frequency data (e. g., Campbell and Perron, 1991 and Hakkio and Rush, 1991). Table 1a presents descriptive statistics. It is evident that LNY, BCR, LNK, TR and DLR have increased steadily during the past 50 years. The respective average annual growth rates are 5.76%, 4.03%, 5.23%, 3.14% and 4.84%.

Data also show that LNY correlates high positively with BCR (0.8915), LNK (0.9909), TR (0.9350) and DLR (0.9116). However, although the contemporaneous correlations between LNY and both BCR and DLR are very high, the correlations between the growth rate of LNY and the level of BCR and DLR are negative ( $-0.0599$ ) and pretty low (0.08) respectively. This phenomenon, similar to those findings in other studies (e.g., Luintel & Khan, 2005), suggests that the relationship between financial development and economic growth in China is a long-run one.

Table 1a.

Summary statistics (1979–2007; 1979 = 100)

LNY BCR LNK TR R (%) DLR

Mean 5.9595 0.5757 6.8545 0.1750 2.9270 0.4696

Median 5.6951 0.5081 6.7032 0.1052 3.0000 0.3331

Std. Dev. 0.8402 0.2464 0.8064 0.1244 5.8214 0.3138

Start value 4.7717 0.1570 5.7636 0.0951 11.7000 0.1356

End value 7.5964 1.0874 8.3258 0.4335 1.5500 1.3737

Econometric methodology-multivariate VAR framework

Suppose that the level of  $Y_t$  can be represented as a non-stationary  $p$ -th order vector autoregression equation:

$$Y_t = \alpha + \phi_1 Y_{t-1} + \phi_2 Y_{t-2} + \dots + \phi_{p-1} Y_{t-p+1} + \phi_p Y_{t-p} + \varepsilon_t \quad (3)$$

According to Hamilton (1994), this VAR( $p$ ) model can be reparameterised as:

$$\Delta Y_t = \alpha + \psi_1 \Delta Y_{t-1} + \psi_2 \Delta Y_{t-2} + \dots + \psi_{p-1} \Delta Y_{t-p+1} + \rho Y_{t-1} + \varepsilon_t \quad (4)$$

where  $Y_t = [LNY, BCR, LNK, R, TR]$  (or  $Y_t = [LNY, DLR, LNK, R, TR]$  in the robustness test) is a  $5 \times 1$  vector of the first-order integrated variables;  $\Psi_s = -\Phi_{s+1} + \Phi_{s+2} + \dots + \Phi_p$  for  $s = 1, 2, \dots, p - 1$  and  $\rho = -\Phi(1)$ ;  $\Psi_i$  are  $5 \times 5$  coefficient matrices;  $\varepsilon_t$  is a vector of normally and independently distributed error terms. Johansen (1988) and Johansen and Juselius (1992) derive the trace test and maximal eigenvalue test to identify the existence and number of distinct co-integrating vector in the VAR framework and Osterwald-Lenum (1992) tabulates appropriate critical values. If there exist  $r$  ( $0 < r < 5$ ) co-integrating vectors, it implies  $\rho$  is rank-deficient, then  $\rho$  can be decomposed as:  $\rho = \pi\gamma'$ , where  $\pi$  ( $5 \times r$ ) and  $\gamma$  ( $r \times 5$ ). Thus, Eq. (4) can be re-written as:

$$\Delta Y_t = \alpha + \Psi_1 \Delta Y_{t-1} + \Psi_2 \Delta Y_{t-2} + \dots + \Psi_{p-1} \Delta Y_{t-p+1} + \pi\gamma' Y_{t-1} + \varepsilon_t \quad (5)$$

where the components of  $\pi$  are the error correction coefficients indicating the speed of adjustment towards long-run equilibrium and the rows of  $\gamma'$  can be interpreted as the distinct co-integrating vectors. Pesaran and Shin (2002) suggest identification of co-integrating vectors through tests of  $r + k$  ( $k \geq 1$ ) restrictions, where  $r$  is the just-identifying restriction proposed by Johansen (1991) and  $k$  is the over-identifying restriction. Each vector requires at least  $r$  restrictions and one of them should be the normalization restriction.

Restrictions must be based on economic theory so that the identified co-integrating vectors could be interpreted as economically meaningful long-run relationships. For an illustration, we assume that there are two co-integrating vectors in our VAR model, which are normalized as economic growth and financial development relationships, respectively. Following Pesaran and



Shin (2002), we need at least five theoretical plausible restrictions on  $\gamma$  vector in order to find out long-run relationships among variables:

(6)

Two normalization restrictions are straightforward, i. e., the coefficients of  $\text{LNY}(\gamma_{11})$  and  $\text{BCR}(\gamma_{22})$  take a value of unity in the first and second vector, respectively. Theoretically, financial development affects economic growth indirectly. Besides, economic theory does not postulate any direct effect from physical capital stock and international trade to financial development.

Thus, the other three restrictions are generated by setting the coefficient of  $\gamma_{12}$  to zero in the first co-integrating vector and setting the coefficients of  $\gamma_{23}$  and  $\gamma_{25}$  to zero in the second co-integrating vector. In addition, in order to identify meaningful co-integration vectors, Wickens (1996) points out that the error correction coefficients (in this case,  $\pi_{11}$  and  $\pi_{22}$ ) must be statistically significant and their signs must be negative.

After identifying co-integrating vectors, we test causality between financial development and economic growth. Johansen and Juselius (1992) point out that a test of zero restrictions on  $\pi$  is the test of weak exogeneity while Hall and Milne (1994) further show that weak exogeneity in a co-integrated system equals the long-run causality. If the null hypothesis  $\pi_{12} = 0$  is rejected, then the economic growth vector is not weakly exogenous with respect to the financial development vector implying financial development does cause economic growth in the long run.

Likewise, if the null hypothesis  $\pi_{21} = 0$  is rejected, then the financial development vector is not weakly exogenous with respect to the economic growth vector implying economic growth does cause financial development in the long run. If the null hypothesis  $\pi_{12} = 0 \wedge \pi_{21} = 0$  is rejected, it implies a bi-directional causality relationship between financial development and economic growth in the long run.

Flow networks are convenient representations of complex material and information transactions. Usually, whatever open self-organizing system behavior is exhibited it is likely to derive from the formal structure of material or energetic interactions within the system and the process of exchange from outside the system (Ulanowicz and Norden, 1990). Thus, a deeper understanding of an evolving system should focus on phenomenological observations and not attempt to explain the evolution of large-scale systems in molecular terms (Ulanowicz, 1997).

In the process of researching system evolution, many scientists, especially ecologists, seek methods for quantifying the system-level properties of flow networks. Ulanowicz, (2003), building on MacArthur (1955) and Rutledge et al. (1976), treated the average mutual information as a cardinal attribute of a developing network and determined that 'ascendency' (A) is the product of average mutual information and the total amount of energy flow in the system. Empirical analysis showed that 'ascendency' correlated well