Sources of Economic Growth in China, 1952-1998
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China has been growing at an average annual rate exceeding 9% for the past 20 years. Many investigators, including Hu (2004) and Wong (2004), are speculating that China is already overheated, but it continues to sustain a high level of growth and it is expected to surpass the GDP of the US in the next few decades. Holz (2005) believes that China will surpass the US GDP by 2015 in terms of purchasing power parity. By 2025, he expects Chinese GDP to be greater than that of any other country in the world by all measures; however, the per capita GDP of China will exceed that of the USA much later. Using the Penn World Tables, he estimates Chinese per capita GDP to exceed the per capita GDP of USA only in 2052. Nevertheless, it has managed to grow at a high rate for a long time. This fact has puzzled many economists and policymakers alike. What are the factors responsible for the high growth rate of the Chinese economy? Is it the increase in labor or capital that is the driving force of China's growth, or is it Total Factor Productivity (TFP) growth? We will try to address this issue in the paper.

This paper estimates a Cobb-Douglas production function along with a time trend to capture the effect of technological progress after the reforms in 1978 for China within a cointegration and Error-Correction modeling framework for the 1952-1998 period. We used an Error Correction Model (ECM) because there was a strong presence of cointegration. Our results indicate that capital has been the most important source of growth in China so far. We estimated the contribution of capital, productivity, and labor's share of growth for the period after 1978 until 1998 and found that capital contributed about 62% of the total growth in GDP. The role of productivity was also high for the same period and accounted for about 28% of the total growth in GDP. Labor contributed the least among the three variables with a share of about 11%. In addition, our ECM indicated that if the growth rate in labor productivity deviates from its long-run equilibrium due to positive or negative shocks in one period, it will move back toward its equilibrium in the next period with a speed of adjustment of about -0.79.

I.   Literature Review

Economists and researchers are divided over whether Chinese growth was propelled by labor and capital growth or Total Factor Productivity (TFP) growth. Krugman (1994) is skeptical about Chinese growth as it was based on a massive use of resources rather than efficient utilization of resources. However, Chow and Li (2003) believe that there has been a significant contribution of TFP since the reforms of 1978. They put the total factor productivity growth at an annual rate of around 0.03 for the period 1978-1998.

On the other hand, some researchers are taking a middle ground. Wang and Yao (2001) claim that there was negative productivity growth before the reforms took place in 1978, but productivity growth was significant for the period 1978-1999. Both factor accumulation and productivity growth have been vital in the growth of the Chinese economy. But how is China going to grow in the future? Holz (2005) sees a very bright future for China. He cites examples of Japan, Taiwan and Korea to show that China is following the same path as they did in their earlier stages of development. Furthermore, he believes that the structural changes taking place in China, along with factor price equalizations, match the standard patterns of growth.

Even though many economists have found a significant impact of TFP growth in the case of China, many East Asian countries did not have a significant growth in TFP. Collins, Bosworth and Rodrik (1996) conclude that there has been only a small role for TFP in the success of East Asian growth in the late 20th century. They did an empirical study of Indonesia, Malaysia, the Philippines, and Thailand, and concluded that savings and investments had a greater role to play in the success of these East Asian countries.

This conclusion has been supported by Lau and Kim (1996). They carried out an empirical analysis of the sources of growth for the Asia-Pacific countries and the Industrialized Western Countries (IWC) and found that capital accumulation was the major source of growth in the Asian region while technical progress was the major source of growth for the IWCs. However, they predicted that sustainable growth is not possible with capital accumulation due to diminishing returns to the factor of production. So, the future growth of Asian countries will be contingent on the research and development work from within the Asian region.

Lim (1994) examined the developing countries of Asia, and he found that the contribution of capital in economic growth was about 65%, and that of labor was 23%. The contribution of technical progress remained low at 14%. This result is somewhat similar to the one obtained by Hossain (2006) for Indonesia in which capital's contribution was about 60%, labor's share was 32%, and that of technological progress was about 8%.

However, as we mentioned earlier, these results are in contrast to those obtained by many other researchers. Chow and Li (2002) found that the role of productivity growth was much greater than that of labor, accounting for almost 32% of the growth of China for the period from 1978 to1998. The contribution of capital was still significantly high at 54%, while that of labor was only about 13%.

On the contrary, the United States experienced a trend with high productivity growth during the 1950s. In the 1950s and the 1960s, the role of productivity growth was tremendous in increasing the per capita income of the United States. But the role of labor became important as earnings per worker became stagnant in the 1970s and the 1980s (Terleckyj, 1990). From then on, however, there has been modest growth in productivity.

Many people dub China as being too labor intensive despite the fact that this hypothesis has been rejected by many studies. Many research papers have shown that capital has been the most important source of economic growth in China so far. But can it be sustained? This is another question that has caught the attention of many researchers and policymakers alike.

Bosworth and Collins (2007) are optimistic about the future growth of China even though they fear that excess capital can be of concern in the future. Since China has a high savings rate of about 40% and they get private capital flows from outside amounting to almost 10% of GDP, there might be overinvestment in the economy. Overinvestment might result in lower profits which will then have a negative impact on employment and production. Furthermore, there are concerns about the financial inefficiency in the Chinese market. However, they believe that China can attain a 10% rate of growth of GDP given the supply side of the economy.[*]

This paper tries to explain the economic growth of China in terms of labor, capital and total factor productivity. Despite legislations to curb excess population growth, China still has an abundant labor supply. So, the labor input will continue to play a significant role in production. We will estimate the growth of the Chinese economy within a cointegration and error correction

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[*]In addition to the high savings rate and capital inflows, China also has made a lot of progress in education. This has increased the quality of labor. Though a lot of inefficiency in the market is seen everywhere, it is improving. So, there is a bright supply side for the Chinese economy.

modeling framework. Akhtar Hossain (2006) explained the sources of economic growth in Indonesia using cointegration and error correction models. Most macroeconomic data are integrated of order one and it is likely that estimating such time series data in level form will lead to spurious regression. In some cases, estimation of variables in level form might generate a stable long-run relation. We will look into the potential unit root problems, cointegration of series and estimate an error correction model if the series are in fact cointegrated. Next, we will discuss the nature of the data and the estimation methodology, and then we will investigate the time-series properties of the variables.

II. Data and Estimation Methodology

A. Data
In order to determine the sources of growth for the Chinese economy, we will use data from 1952-1998 obtained from Chow and Li (Chow and Li, 2002). Considering the fair amount of difficulty in constructing the capital stock series for China, we decided against updating the data set with information for recent years. The nominal GDP and labor force data are obtained from the Statistical Yearbook of China (SYC) with adjustments for inflation in the case of GDP. Chow and Li (2002) calculate capital series based on a series of equations with different rates of depreciation for different periods (for details, see Chow and Li, 2002).

It is important to note the potential measurement problems that exist with the official data and the data generated from them. For instance, there was an incentive for the officials to report higher growth as higher growth would be regarded as being more efficient and would help the officials in their promotion.[*]

Another issue pointed by Woo (1997) is that the GDP growth rates are not calculated on the basis of constant base year prices. As the base year prices vary for different periods, it makes it difficult to adjust the growth rates to a constant base. Woo writes that the growth rates in the period 1980-1990 were based on the 1980 prices, while the growth rates from 1991 onwards were based on 1990 prices. Since, the ratio of prices in the agricultural sector relative to industrial sector were higher in 1990 than in 1980, and given that the industrial sector was the biggest sector contributing towards growth in 1985-1993, its impact will be lower when measured in 1990 prices compared to 1980 prices.

In addition, for reasons mentioned by Chow and Li in their 1993 paper, we do not include the sample period from 1958-1969. During this period, the output was highly volatile and the statistical bureau was almost non-functional. There was a tendency for officials to overestimate output. Chow (1993) termed these years as abnormal ones and thus discarded them from the regression to generate a better estimate of the production function.

On the other hand, there are quite a few scholars who support the official Chinese statistics. Klein and Ozmucur (2002-3) criticize other scholars for failing to see quality adjustments and a broad set of indicators while estimating the level of GDP. Klein and Ozmucur argue that no estimates can be assumed to be entirely correct, but since their calculations are based on several strategic indicators that move along with the official statistics, it is fairly rational to believe that official statistics are not overestimated.

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[*] The focus of the managers was on output because one of the ways to get promoted was to maximize output. Profits did not have much significance when considering the promotion of an individual. So, the managers could overstate output, post low profits and still be considered for promotion. This trend could have had significant impact on the production statistics.

B. Estimation Methodology

Many traditional production functions start out with output as a function of the basic factor inputs, viz. capital, labor and technology. We will use a Cobb-Douglas production function for the Chinese Economy for the period 1952-1998, excluding the years 1958-69 for reasons cited above. Since the economic reforms began in China in the year 1978, we will follow the approach taken by Chow and Li (2002) and add a trend variable to distinguish the years after the reform. The trend variable represented by t in the regression has values equal to zero for years before 1978, 1 for 1978 and increasing thereafter by 1 for every year. We will take the log on both sides of the Cobb-Douglas function to get the following:

$$\ln GDP_t = \beta_0 + \beta_1 \ln K_t + \beta_2 \ln L_t + \beta_3 t \qquad (1)$$

where GDP represents real gross domestic product, K represents the capital stock, and L the labor force. All the units are in millions of Yuan and valued in 1978 prices. Now, we can calculate the per capita GDP by assuming constant returns.

$$Ln(GDP/L)_t = \beta_0 + \beta_1 \ln(K/L)_t + \beta_2 t \qquad (2)$$

Differentiating this equation with respect to time will give us per-capita GDP growth rate.

$$GDPg = \beta_0 + \beta_1 Kg \qquad (3)$$

where g represents the growth rate and GDP=GDP/L, K=K/L

As we indicated before, most of the variables in macroeconomics are integrated of order one. That is, it is necessary to take the first difference to render the series a white noise process. At the same time, it is possible that series like GDP, capital and labor are non-stationary, and when estimated in a regression they might cancel each other out so that the residuals of the regression are stationary. This means that not only will we have to check for the presence of a unit root in each of these variables in level form, but also in the residuals of the production function regression. The presence of a unit root in the variables and the absence of a unit root in the residuals of the regression would imply the presence of a cointegrated relationship among the variables. This is due to the fact that there exists a linear combination of these I (1) variables that is stationary or I (0). Hence, this would allow us to estimate an error correction model.

III. Time Series Properties of the Variables & Engle-Granger Approach

Output, capital and labor are generally trended upwards over time. As capital and labor grow, output also tends to grow. As output grows, it demands a greater use of capital, thereby increasing the production of capital goods. On the other hand, population is continuously increasing in most of the countries of the world. So, it is fairly easy to see that these variables are non-stationary. In this case there is a high chance that there will be a linear combination which is stationary and therefore error correction methods will have to be applied. This is a new approach that is superior to the ordinary least squares approach taken by Chow & Li (2002).

We will apply different tests to check for the presence of unit root in the variables. First we will look at the correlograms, and then we will apply the ADF and Phillips-Perron tests to determine whether the variables suffer from the unit root problem.

From the correlogram of the log of real GDP, log of Capital and the log of Labor, it can be readily seen that all these variables have a unit root in level form. We also apply unit root tests to ensure that our results are consistent. Since the series are non-stationary, we take the difference of logs and look at the correlograms. The ADF and Phillips-Perron tests show that the first difference of the log of real GDP and labor are stationary. However, the first difference of the log of capital is integrated of order 2, and thus we have to take the second difference of K to make it stationary.

We estimated the production function in level form with all the variables showing the presence of unit roots. The variables were not of the same order of integration, however. Real GDP and labor were of I (1) but capital was I (2). However, the residuals of this estimation do not have a unit root at the 5% level. Since all three variables exhibit a unit root in level form, and the residuals of the estimation do not have a unit root, they form a cointegral relationship. It is therefore possible to utilize the two-step Engle-Granger approach to estimate the error correction model. In the two-step Engle-Granger approach, we will first estimate output as a function of labor and capital with a trend variable in level form.

$$\text{Ln GDP}_t = \beta_0 + \beta_1 \ln K_t + \beta_2 \ln L_t + \beta_3 t + e_t \qquad (4)$$

Since all these variables have unit roots in level form, and are cointegrated, the resulting residuals from the estimation of the equation are stationary. In view of this, we will take the difference of the variables and estimate an equation that reconciles the short-run and long-run behavior of these variables. In the error correction model, the percentage change in real GDP is a function of the percentage change in capital, labor and the residuals lagged one period from the equation in level form.

$$\Delta \ln \text{GDP}_t = \beta_0 + \beta_1 \Delta \ln K_t + \beta_2 \Delta \ln L_t + \beta_3 t + e_{ct-1} + V_t \qquad (5)$$

Where $e_{ct-1} = $ residuals from the previous regression lagged one period, and V_t refers to a random error term. In this equation, β_1 and β_2 measure the short-run impact of capital and labor, respectively.

If we get a negative sign for the coefficient of e_{ct-1} , we can conclude that there will be short-term adjustments in the percentage change of real GDP back towards its long-run equilibrium level. Initially, we assumed that our production function follows constant returns to scale. Our results show that the production function in fact exhibits constant returns to scale. So, we will estimate the equations in per capita form.

$$\text{Ln } (\text{GDP}/L)_t = \beta_0 + \beta_1 \ln(K/L)_t + \beta_3 t + e_t \qquad (6)$$

Since the residuals of this estimation do not exhibit unit root at the 5% level, there is cointegration. We will use the residuals from this estimation to estimate the short-run dynamic error correction model given below.

$$\Delta \ln(\text{GDP}/L)_t = \beta_0 + \beta_1 \Delta \ln(K/L)_t + e_{ct-1} + V_t \qquad (7)$$

IV. Discussion of the Results

We found that the series are cointegrated, and thus we will follow the two-step Engle Granger approach to estimate the production function. Let us start with the estimation of the production function in level form.

Table 1: OLS Results of Estimation of Production Function in Level Form

Dependent Variable: Ln GDP
Sample: 1952-1957, 1970-1998
Adj. R-squared: 0.997759
F-statistic: 5046.330

Independent Variable	Coefficient	t-statistic	p-values
Ln Labor	0.439173**	2.159413	0.0387
Ln Capital	0.603312*	7.680673	0.0000
Trend	0.026394*	10.66908	0.0000
Constant	1.804701*	3.877316	0.0005

Note: * means significant at 1% level, ** means significant at 5% level.

As we can see from the above table, the sum of the coefficients of the log of capital and the log of labor is about one. This means that we can re-estimate the production function in per-capita form to find out the sources of economic growth in China for the period 1952-1998 excluding the years 1958-1969.

Table 2: OLS Results of Estimation of Production Function in Per-Capita Level Form

Dependant Variable: Ln GDP/Labor
Sample: 1952-1957, 1970-1998
Adj. R-squared: 0.994335
F-statistic: 2984.744

Independent Variable	Coefficient	t-statistic	p-values
Ln Capital/Labor	0.628031*	24.72004	0.0000
Trend	0.026235*	10.96096	0.0000
Constant	1.664361*	8.529221	0.0000

Note: * means significant at 1% level.

From the above estimation, the elasticity of labor productivity with respect to the capital-labor ratio is about 0.63. The assumption of constant returns to scale implies that the output elasticity for labor will be about 0.37. In addition, the above estimation shows that the average rate of technological progress is about 0.026 for the whole sample period.
From our estimation above, we can write the output equation as follows:

$$GDP = 0.026 + 0.63\, K + 0.37\, L \qquad (8)$$

Hence, for the two sample periods, we can estimate the contribution of capital and labor by multiplying the coefficients by their exponential growth rates over the same period.

Now, assuming the growth rates for the variables are exponential, we can calculate the exponential growth rate of X from time t=a to t=b as follows:

$$\text{Exponential Growth} = (\ln(X(t=b))-\ln(X(t=a)))/(b-a) \qquad (9)$$

Based on the above formula, we calculated the real GDP growth rate to be about 7.6% for the whole sample period. Real GDP exponential growth rates were about 6% for the period from 1952-1978 and about 9.3% for the period 1978-1998. Similarly, the exponential growth of capital and labor for the period 1978-1998 was about 9.14% and 2.78 % respectively. The contribution of capital, labor and productivity to GDP growth can be summarized in the following table.

Table 3: Sources of Growth (1978-1998)

Source	Contribution (% of GDP growth)
Capital	62%
Productivity	28%
Labor	11%

As can be seen in the table above, capital has been the most important source of growth for the period from 1978-1998 while productivity increase has also accounted for a 28% of the growth. At the same time, labor's share is at 11%. Our results differ slightly from that of Chow and Li (2002) possibly due to the fact that we have not corrected for serial correlation. We are estimating an error correction model, and thus, it does not make sense for us to use AR(1) terms to correct for serial correlation.

As indicated earlier, we can reject the null hypothesis of unit roots in the residuals only at 5% level in the above equation. In addition, the total contribution from these sources exceeds 100% due to the rounding off of figures at various stages of the calculation process.

We have to take these results with caution. We still suffer from some serial correlation in the estimation which might be the effect of omitted variables. For instance, labor cannot really be taken as it is but rather should be updated to account for its quality. Moreover, the openness of the economy also might have had a significant impact on the growth rate considering the dramatic opening of China to the world market in recent years.

Table 4: Error Correction Model for Per-Capita GDP Growth rate

Dependent Variable: $\Delta\ln(GDP/L)_t$
Adjusted Sample: 1954-1957, 1972-1998
Adjusted R-squared: 0.537676
F-statistic: 12.62985
Durbin-Watson Statistic: 2.038367

Independent Variable	Coefficient	t-statistic	Probability
$\Delta\ln(K/L)_t$	1.039221*	5.205338	0.0000
ECT(-1)	-0.790679*	-3.207939	0.0034
Constant	-0.004907	-0.221861	0.8261
AR(1)	0.686515*	3.367082	0.0023

Note: * indicates significant at 1% level

Since the variables had a cointegrating relationship, we can estimate a dynamic error- correction model for the production function in per-capita form. These variables are stationary, and thus we will use the normal OLS procedure to estimate the equation.

As expected, we have a negative sign for the coefficient of the error-correction term lagged one period and it is significant at 1% level of significance. This means that if the growth rate in labor productivity deviates from its long-run equilibrium by 10 percent due to positive or negative shocks, it will revert back towards its equilibrium level in the next period by 7.9 percent. Hence, the coefficient of the error-correction term measures the speed of adjustment towards the long-term equilibrium. Furthermore, the first difference of the log of K/L, which measures the short-run impact, is significant at the 1% level of significance. The Adjusted R-squared may be somewhat low considering the time-series nature of the data.

If we look at the in-sample (historical) forecasts, however, the ECM model performs relatively well. The Theil Inequality coefficient is 0.21, which is well below the 0.30 threshold level implying that our model is able to track the turning points in the actual series. The variance is relatively low at 0.15, while the covariance is a respectable 0.85.

Graph 1: In-Sample Forecast of $\Delta\ln(\text{GDP/L})_t$
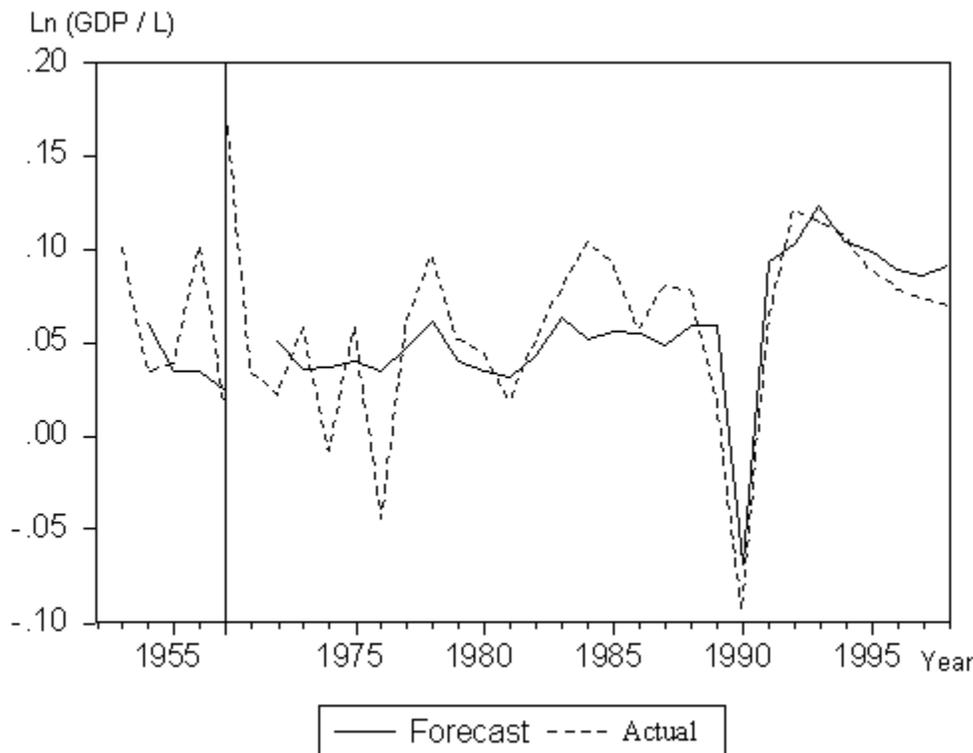
Unit root tests for the residuals reject the null hypothesis of a unit root at the 1% level. Unit root tests were conducted without an intercept and trend using the ADF and Phillips-Perron methodology. Again, we have to be somewhat cautious about these results given that the tests for unit roots tend to have relatively low power.

Initially, we estimated the error correction model without the AR(1) term, and found the presence of serial correlation in the residuals. This might be largely due to omitted variables in the model. As indicated earlier, there are several other variables which affect the growth rate of output, and we have used the traditional Cobb-Douglas production function as a basis for our regression analysis. In the model discussed above, once we included an AR(1) term, the residuals in our model no longer exhibited first order serial correlation.

Our estimates represent a significant positive contribution to the literature. There is a stable and long-term (cointegrated) relationship among the variables in the production function, and hence the error-correction method is the econometrically appropriate way to account for the growth in output. We thus address one of the more important econometric issues raised by Chow and Li (2002). The contribution of capital, labor and productivity in growth are largely similar to those obtained by Chow and Li (2002).

V. Conclusion

This paper estimates a Cobb-Douglas production function along with a time trend to capture the effect of technological progress after the reforms in 1978 for China within a cointegration and error-correction modeling framework during the period 1952-1998. We found the presence of cointegration and hence an error correction model is the most appropriate model for the estimation of the production function. Our results indicate that capital has been the most important source of growth in China so far. We estimated the contribution of capital, labor, and productivity, and found that capital contributed about 62% of the total growth of output. The role of productivity was also high for the period in question, and it accounted for about 28% of the total growth of GDP. Labor's share was the least important, with a share of about 11%. Our results are largely similar to those obtained by Chow and Li (2002). In addition, our ECM indicated that if the growth rate in labor productivity deviates from its long-run equilibrium due to positive or negative shocks in one period, it will move back toward its equilibrium in the next period with the speed (ratio) of adjustment of about -0.79.

We have to take the results with caution. There is still some serial correlation present in our (uncorrected) ECM model, which might be largely due to omitted variables. Furthermore, our discussion of the data revealed several problems with relying on official statistics. Our results may be significantly affected if the problems mentioned above in the data section are severe. Moreover, we have not been able to update the data for recent years, and thus the results reported in this paper may have less significance in terms of policy implications. We recommend further research in this area with updated data to get a better understanding of the growth process in China in recent years.

VI. References

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