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A TIME SERIES ANALYSIS OF LONG TERM CAPITAL FORMATION IN INDIA

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ABSTRACT

This paper studies the capital formation in the Indian Economy over a 34 year period between 1970 and 2004. Three measures of capital formation including Gross Fixed Capital Formation, Gross Domestic Capital Formation, and Net Domestic Capital Formation are studied. Special attention is paid towards any potential impact of economic liberalization on capital formation in India. All the measures of capital formation have strongly positive time trends. Economic liberalization is found to have no statistically significant impact on any measure of capital formation.

Introduction

India is often at the center of global media attention these days. Once poor, underdeveloped, malnourished country is getting great global media attention because of her rapid progress, and increasing economic power. Once investment starved Indian economy is now flexing its economic might and acquiring big international companies. In information technology sector, India has become synonymous with progress and innovation.

Year 2007 marks the 60th year since India's independence from the British colonial rule. But the major part of this rapid progress happened in a relatively short period of less than two decades. By most of the common accounts, a watershed change in the Indian economy took place since the economic liberalization in 1990-91. Economic liberalization did not take place out of choice. It was more or less a matter of compulsion. This was arguably the only way out to take the economy steer clear of bankruptcy.

Liberalization was implemented with a lot of trepidation. It was feared that the opening up of the economy would also make the domestic sector vulnerable to global economic forces. Time has proved much of this fear to be misplaced. Indian economy not only withstood the forces of globalization but also thrived admirably, economically speaking. After decades of complacent "Hindu Rate of Growth" hovering around 3-3.5%, Indian economy seems to be on a steady path of 7-8% annual growth rates. It survived one of the worst financial crises of the twentieth century with very little scar. The economy steadily increased income and wealth. The magnitude of poverty has also fallen steadily over the years.

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Remarkably, Indian economy has steadily augmented the capital stock available for productive purposes. Generations of economists and social thinkers have emphasized the importance of capital formation on growth and development (Greenwood and Hercowitz, 1991, Harrod, 1939, Jorgenson and Griliches, 1967, Kaldor, 1963, Kendrik, 1976, Kuznets, 1973, Marx and Engels, 1975, Ricardo, 1817, Smith, 1776 (1937), Srinivasan, 1964) It has been long held that a country's ability to embark on virtuous cycle of growth infinitely long process of rural-urban migration and economic expansion. A relatively elastic supply of capital may be related to that phenomenon (Lewis, 1954).

Capital labor ratio has occupied one of the most important places in the discussions regarding Indian development process (Chakravarty, 1998, Goldar, 1983) It has been argued that a country with large population base could potentially continue with an and economic prosperity critically depends on the pace of capital formation in that country. Moreover, high capital availability is also a necessary factor for high labor productivity.

Capital formulation is also inalienably related to the issues of technological progress, innovations, and changes in productivity over time (Barro and Sala-i-Martin, 1995, Blanchard and Fischer, 1989, Jorgenson and Griliches, 1967, Lucas, 1988) Capital formulation has figured prominently in the international comparisons of economic growth and environmental issues (Klein, 1983, Maddison, 1982, Uzawa, 1996)

In this paper I look at the long term capital formation in the Indian economy. In particular, I address two questions: (1) did economic liberalization have a significant impact on the capital formation in India? And (2) has the rate of formation of capital hastened since the time of liberalization?

I look at three specific measures of capital formation in India: (1) gross fixed capital formation, (2) gross domestic capital formation, and (3) net domestic capital formation.

I analyze data for the years 1970-2004. During years, Indian economy has been subjected to war, military conflicts especially with neighboring South Asian nations, domestic militancy and terrorism, multiple changes in governments of different political shades, political assassinations of great shocks, stock market crashes and booms, financial scams, multiple crop failures, droughts, floods, global oil crisis, and economic liberalization. All these factors have potentially non-trivial impact on capital formation.

In the remainder of the paper I do the following: (1) discuss the frameworks of rudimentary economic theories that are useful to understand the effects of capital formation on productivity and growth, (2) discuss the data, (3) provide basic aspects of time series analysis theories that are employed to analyze the time series of capital formation data, and (4) discuss the findings.

The effect of capital formation on production

Let us assume that there are two main inputs to production, labor and capital, denoted by L, K . Choosing Q to denote the quantity of production we can write a simple

production function as $Q = f(L, K)$. Furthermore, we may assume that the marginal products of the inputs are non-negative. Formally, $\frac{\delta Q}{\delta K}, \frac{\delta Q}{\delta L} \geq 0$. Non-negativity of the marginal products simply implies that the total production cannot be reduced if we increase any or both of the inputs.

Additionally, if the production function exhibits diminishing marginal products then as the level of use of an input increases, marginal product for that input decreases. Formally, $\frac{\delta^2 Q}{\delta K^2}, \frac{\delta^2 Q}{\delta L^2} < 0$.

A homogenous production function of degree *t* simply exhibits the property that $Q = f(\eta L, \eta K) = \eta^t f(K, L)$. If $0 \leq t < 1$ then the production function exhibits Decreasing Returns (DRS) to Scale. For $t = 1$, the production function exhibits Constant Returns to Scale (CRS) and for $t > 1$, the production function exhibits Increasing Returns to Scale (IRS.)

There is a straightforward interpretation for the returns to scale. If we increase both the inputs by 100% then the resultant output will grow by less that 100% under DRS, by exactly 100% under CRS and by more that 100% under IRS.

The importance of capital formation may be easily understood by discussing the case of a standard Cobb-Douglas production function of the type $Q = AK^{\alpha} L^{\beta}$ and $0 < \alpha, \beta < 1$. Here, *A* denotes the type of technology that is being used. A higher *A* will be consistent with a more productive technology. It is easy to verify that the returns to scale for this production function will depend on the value of $(\alpha + \beta)$.

Marginal product of capital and labor may simply be derived to be

$$MP_K = \frac{\delta Q}{\delta K} = A\alpha K^{\alpha-1} L^{\beta}$$

$$MP_L = \frac{\delta Q}{\delta L} = A\beta K^{\alpha} L^{\beta-1}$$

Note that the level of marginal products of labor is higher if the level of *K* is higher. This is easily concluded by observing

$$MP_{LK} = \frac{\delta^2 Q}{\delta L \delta K} = A\alpha\beta K^{\alpha-1} L^{\beta-1} > 0$$

In other words, a more productive labor force needs higher endowment of capital. Furthermore, note that

$$\frac{\delta^2 Q}{\delta K^2} = A\alpha(\alpha - 1) K^{\alpha-2} L^{\beta} < 0$$

and

$$\frac{\delta^2 Q}{\delta L^2} = A\beta(\beta - 1) K^{\alpha} L^{\beta-2} < 0$$

Both of these are consistent with diminishing marginal products for both capital and labor.

It may be pointed out that increasing returns to scale production functions have also been studied extensively in the context of economic growth (Matsuyama, 1991). Following the discussion on basic aspects of a production function a simple model of neoclassical growth is presented. Elements of the model could be found at several excellent sources including (Barro and Sala-i-Martin, 1995, Blanchard and Fischer, 1989, Harrod, 1939, Kuznets, 1973, Ramsey, 1928, Samuelson, 1970, Solow, 1956)

Let us take a twice continuously differentiable homogenous CRS production function $Q = F(K, L)$ that exhibits positive and diminishing marginal products for both labor and capital (like the one discussed above.) Furthermore, following (Inada, 1963) assume that $\lim_{K\to 0}(F_K) = \lim_{L\to 0}(F_L) = \infty$ and $\lim_{K\to\infty}(F_K) = \lim_{L\to\infty}(F_L) = 0$.

CRS helps us to write the following:

$$Q = F(K, L) = L.F(K/L, 1) = L.f(k)$$

or

$$Q/L = q = f(k)$$

Note that $k = K/L$. Now, let us define a simple motion equation for the capital accumulation of the type $K' = I - \delta K = sF(K, L) - \delta K$ where K' is the rate of change of capital over time, s denotes the savings rate in the economy, I denotes investment, and δ denotes the rate of depreciation. Simply, the motion equation means that the rate of change of capital stock over time is the difference between savings and the depreciation. Hence, during the time of capital accumulation, the rate of change of capital over time will be positive.

Note that the rate of change of capital-labor ratio (K/L) is simply defined to be $k' = \frac{\delta(K/L)}{\delta t} = (K'/L) - (L'/L)(K/L) = (K'/L) - nk$ where n is the growth rate of population over time. Now, dividing both sides of the motion equation for the capital accumulation we get $k' = sf(k) - (n+\delta)k$. Note that $(n+\delta)$ could simply be interpreted as the effective rate of depreciation (Barro and Sala-i-Martin, 1995, Blanchard and Fischer, 1989).

If the economy is in steady state then $sf(k^{ss}) = (n+\delta)k^{ss}$ where k^{ss} is the steady state capital-labor ratio. Solution to this equation will help us find the value for k^{ss}. Also note that in steady state, the output per unit of labor can simply be expressed as $q^{ss} = f(k^{ss})$ and the steady state consumption is easily derived to be $c^{ss} = (1-s)f(k^{ss})$ (Barro and Sala-i-Martin, 1995, Blanchard and Fischer, 1989). The Golden Rule of the capital accumulation simply suggests that $f'(k^{ss}) = n + \delta$ (Barro and Sala-i-Martin, 1995, Blanchard and Fischer, 1989, Galor and Ryder, 1989, Harrod, 1939, Ramsey, 1928, Solow, 1956, Phelps, 1966).

It may be clarified here that the steady state is characterized by the constancy of per-capita consumption, capital stock, and output. On the other hand, Golden Rule attempts to find the maximum possible steady state path attainable for the economy.

Data, Methods, and Results

Data for the Gross Fixed Capital Formation, Gross Domestic Capital Formation, and Net Domestic Capital Formation are obtained from the Reserve Bank of India's database on Indian economy. These figures are reported at the gross level. For purposes of this paper, these gross figures are converted into per-capita amounts. This is done to ensure that this analysis is consistent with the theory that is primarily concerned with the capital-labor ratio.

Computing the yearly per-capita amounts are particularly challenging for the Indian case. Annual data on population is hard to find and oftentimes not reliable. Usually, population data collected during the decennial censuses are more reliable. Using the Economic Survey of India, decennial population is collected for the years 1971, 1981, 1991, and 2001.

Note that the capital formation data is reported for the fiscal year but population data is reported for the calendar year. I treat 1971 population data true for the 1971-72 fiscal year. Similarly, 1981 population data is imputed to the fiscal year 1981-82, 1991 population data is imputed to the fiscal year 1991-92, and 2001 population data is imputed to the fiscal year 2001-02.

Decadal growth rates of the population are computed in the following way: Suppose Pop_t is the population in year t and Pop_{t+10} is the population in the year $t+10$. Denoting g to be the growth rate of population we see that $Pop_{t+10} = (1+g)^{10} Pop_t$. In other words, $(1+g)^{10} = Pop_{t+10} / Pop_t$ or, $g = (Pop_{t+10} / Pop_t)^{0.1} - 1.$

Using the decadal growth rates of population calculated using the method described above population figures for each of the years are computed. This figure is used to derive the capital formation data for each year between 1970-71 and 2003-04. I assume that 2001 to 2004 period also exhibited the same rate of population growth as observed between 1991 and 2001. Basic data is presented in Table 1 and plotted in Figure 1 for visual inspection.

Data presented in Table 1 shows that per-capita GFCF, GDCF, and NDCF have all more than tripled over the 34 years' time period analyzed in the paper. This is especially significant since population has roughly doubled during the same time period. This implies that both the absolute stock of capital and the per-capita availability of capital have rapidly increased during these years. The rates also seem to be different during pre and post liberalization. For example, during 1970-71 and 1990-91, GFCF increased by roughly 80-83%. The same relative magnitude of increase has happened in a short time of less than a decade and a half between 1990-91 and 2003-04.

It is often argued that economic liberalization has ushered the Indian economy in rapid pace of growth and prosperity. It is also posited that economic liberalization has contributed greatly towards improving the productivity and efficiency of the economy.

Although capital accumulation has taken place relatively steadily over three decades analyzed in this paper, it will be definitely useful to check if the conjecture regarding economic liberalization is true.

But disentangling the time series properties remains a critical challenge for any aggregate data. Time series data like the ones under consideration here definitely get affected by severe autocorrelation. Additionally, strong trend effects are regularly observed for aggregated time series data. To completely unravel the properties of the data, we will have to control both for trend effect and the autocorrelation effect. For a good overview and introduction to the complexities of modeling time series data, refer to (Dickey and Fuller, 1979, Hamilton, 1994, Fuller, 1976, MacKinnon, 1994).

Without testing for the complete time series properties, I just look at few simple OLS regressions. A simple lagged regression could be estimated by employing the equation $y_t = \rho y_{t-1} + \varepsilon_t$ where $\varepsilon_t \sim^{iid} N(0, \sigma^2)$. The estimated value of the autocorrelation parameter is simply given by

$$\hat{\rho} = \frac{\sum y_{t-1} y_t}{\sum y_t^2}.$$

If $|\rho| < 1$ then $\sqrt{n}(\hat{\rho} - \rho) \sim N(0, 1-\rho^2)$.

Tables 2, 3, and 4 report results of various regressions of the capital formation data on lagged values and indicator variable for economic liberalization. All the measures of capital formation have very strong positive trends. But controlling for lagged values, the effects of trends tend to be softer. Controlling for lagged variable, only the trend of the Net Domestic Capital Formation is significant at 5% level.

It is clear from Table 4 that there is no statistically significant impact of liberalization on any measure of capital formation. The indicator variable for economic liberalization is not statistically significant in any case. It seems that the lagged value is the one that is statistically of most importance.

Conclusion

This paper analyzes the effects of economic liberalization on the capital formation in the Indian economy. Three major forms of capital formation, Gross Fixed Capital Formation, Gross Domestic Capital Formation, and Net Domestic Capital Formation are studied in this paper. All the measures of capital formation have strongly positive time trends. This study reveals that there may be not statistically significant impact of economic liberalization on capital formation in India. Lagged values are of most importance while determining the current values of capital formation.

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TABLE 1
Basic Data (All Monetary Values are In Constant Units, Base 1993-94)

Year	Per-capita Gross Fixed Capital Formation (Rupees Thousands)	Per-capita Gross Domestic Capital Formation (Rupees Thousands)	Per-capita Net Domestic Capital Formation (Rupees Thousands)	Population (in Thousands)
1970-71	112864	120606	77064	535944
1971-72	115587	121687	77109	548160
1972-73	118556	116506	70660	560376
1973-74	112257	134508	87574	572864
1974-75	106407	117224	69255	585631
1975-76	115677	119688	70363	598682
1976-77	127163	131103	80168	612024
1977-78	137078	144883	92598	625664
1978-79	133509	164288	110188	639607
1979-80	125414	142072	86226	653861
1980-81	135661	149183	91507	668433
1981-82	142728	146964	87292	683329
1982-83	143477	143633	81604	698113
1983-84	147229	145515	80980	713216
1984-85	152112	154488	87120	728646
1985-86	157956	165383	95700	744410
1986-87	163156	162458	90319	760516
1987-88	174304	182957	108183	776969
1988-89	184473	202527	124880	793779
1989-90	193413	212154	131273	810952
1990-91	205708	236151	152306	828497
1991-92	197928	202680	115524	846421
1992-93	206214	217216	126620	863094
1993-94	209401	225444	130735	880096
1994-95	229606	271755	170959	897433
1995-96	268566	296155	187806	915111
1996-97	267364	287669	172708	933137
1997-98	267785	303786	183074	951518
1998-99	285435	299889	173951	970262
1999-00	306044	355400	224943	989375
2000-01	312469	343636	208732	1008864
2001-02	319488	327087	188601	1028737
2002-03	337546	376704	235075	1049002
2003-04	363006	420261	273978	1069665

Figure 1

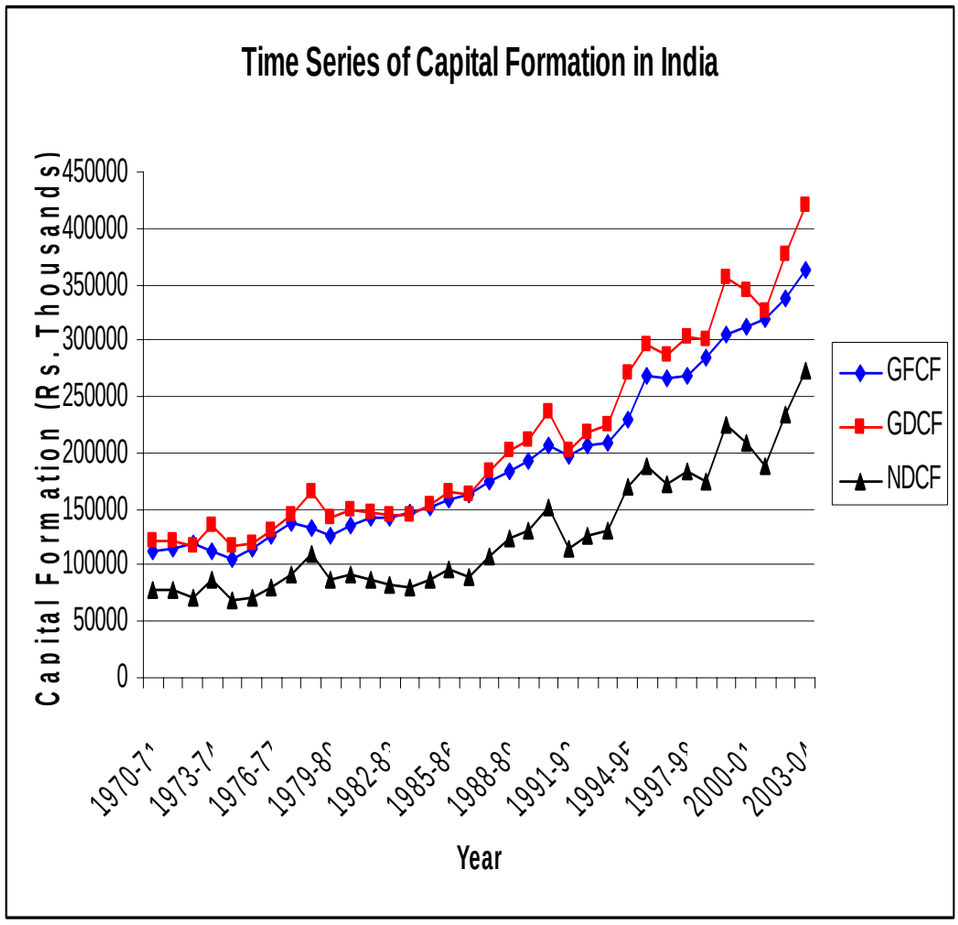

TABLE 3
Trend Regressions
(Student's t-Values in Parenthesis)

Regressions	GFCF	GDCF	NDCF
Time	7242.85 (18.18)	8177.69 (15.39)	4997.45 (11.94)
Constant	66649.57 (8.34)	66939.11 (6.28)	40340.96 (4.81)
Adjusted R-Squared	0.91	0.88	0.81

TABLE 3
Trend Regressions With Lagged Variables
(Student's t-Values in Parenthesis)

Regressions	GFCF	GDCF	NDCF
Lagged Variable	0.953 (12.58)	0.833 (6.57)	0.696 (4.36)
Time	830.85 (1.51)*	1982.58 (1.90)**	1949.64 (2.39)
Constant	1411.49 (0.24)*	7464.79 (0.69)*	8329.69 (0.88)*
Adjusted R-Squared	0.99	0.95	0.88

* Statistically not significant.
** Statistically significant at 10% level.

TABLE 4
Trend Regressions With Lagged Variables, and Indicator for Liberalization
(Student's t-Values in Parenthesis)

Regressions	GFCF	GDCF	NDCF
Lagged Variable	0.956 (11.96)	0.829 (6.08)	0.685 (3.97)
Time	848.93 (1.47)*	1961.74 (1.79)**	1886.75 (2.10)
Dummy for Liberalization	-849.54 (-0.13)*	1048.57 (0.07)*	2555.33 (0.18)*
Constant	913.95 (0.13)*	8072.35 (0.59)*	9725.24 (0.80)*
Adjusted R-Squared	0.99	0.95	0.88

*: Statistically NOT significant.
**: Statistically significant at 10% level.