Which Second-Generation Endogenous Theory Explains Long-Run Growth of a Developing Economy?

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Abstract: This paper uses various measures of research activity to test whether the second-generation endogenous growth models are consistent with aggregate time series data and micro-level data for a developing and reforming economy – India. Findings indicate limited support for the semi-endogenous and Schumpeterian models using aggregate data, whereas the firm-level data supports only the Schumpeterian models.

JEL Classification: O3, O4
Key words: Schumpeterian growth theory, semi-endogenous growth theory

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1. Introduction

The second-generation growth models try and resolve the "scale effects" problem embedded in the first-generation models, according to which, the TFP growth of an economy is directly related to the level of resources devoted to R&D. Jones (1995) challenges this assumption, and gathers evidence for the US and G5 economies which suggests that whereas the level of R&D expenditures and R&D workers in these economies has steadily increased over time, TFP growth has stagnated. In order to sterilize the effects of scale on TFP growth, two versions of the second-generation growth theories have been developed. The 'semi-endogenous" growth models of Segerstrom (1998), Jones (1995) and Kortum (1993) relax the assumption of constant returns to knowledge maintained by the first-generation models. Instead, these models assume diminishing returns to knowledge. The implication of this assumption is that, as knowledge becomes more complex, an ever increasing quantity of resources are required to be devoted to the R&D sector in order to maintain a constant TFP growth rate. Therefore, these models suggest that a positive growth in R&D is required to sustain TFP growth. In these models, steady state growth is invariant to policy changes. On

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the other hand, the fully-endogenous "Schumpeterian" models proposed by Dinopoulos and Thompson (2000), Howitt (1999) and Aghion and Howitt (1998) maintain the assumption of constant returns to knowledge. These models argue that the increasing level of resources devoted to R&D spread thinly over the concomitantly increasing product variety in the economy, which sterilizes the effects of R&D productivity. The underlying argument here is that as the economy progresses, the possibility of people/firms entering the industry with new products also increases. Aggregate R&D expenditures and R&D workers spread over this increasing variety of products of the incumbent and new firms. In these models, long-run growth remains robust to policy changes.

Several papers have tried to test the predictions of these two competing theories using time series data for either the US and/or OECD economies (Madsen, 2008; Ha and Howitt, 2007; Zachariadis, 2003, 2004). These studies find convincing support for the Schumpeterian theory, but only limited or no support for the semi-endogenous theory. However, to the best of my knowledge, no attempt has been made to test the validity of these theories using data for developing economies, for which, implications of these R&D based theories remain unclear to date (Jones, 1995a). This is because these economies are not at the forefront of knowledge creation, which is a key feature, embedded in these models.

In this context, the present chapter provides further insights into the growing body of literature on the second-generation growth models by using long time series data and firm-level data, drawing on the experience of one of the largest and fastest growing developing countries in the world – India, which is an ideal candidate to test the validity of these theories for a number of reasons. First, it was a "closed" economy without any beneficial trade and investments – both inward and outward - for the first four decades of its independence until 1991. Secondly, the Indian industry was highly regulated during this period, with strict controls on manufacture of new products, entry of new firms and capacity expansion (Ahluwalia, 1991). R&D in India during this period was geared more towards imitation rather than innovation. It is interesting to note that the average real R&D intensity (R&D/GDP) in India over the period 1950-2005 is in the vicinity to that of the OECD economies, however, patents filed or granted to Indian residents remain abysmally low, compared to these economies. In this situation, the assumption of decreasing returns to scale maintained by the semi-endogenous models, may not be tenable for a developing economy like that of India. This is because it may have only discovered only the most basic ideas to start with.

Therefore, returns to the already available stock of knowledge, inclusive of the knowledge developed elsewhere, may in fact be constant or even increasing for this economy and other such economies. Moreover, as pointed out above, until 1991, the regulatory framework had placed strict controls on manufacture of new products by a firm as well as entry of new firms – both of which constitute the product proliferation hypothesis on which the "Schumpeterian" models rely. Therefore, it remains to be seen whether these theories are consistent with either long time series data or micro-level data from India.

Other than the use of graphical analysis and co-integration tests for examining these theories, empirical analysis is also conducted not only to complement the results based on co-integration tests, but also with a view to extending the scope of this study in trying to delineate some of the factors explaining TFP growth of a developing economy. The empirical analysis focuses on the role of international technology spillovers, absorptive capacity, and distance to frontier. Interestingly enough, no study to date, has tried to explore the determinants of India's growth process. This question assumes great significance currently, as this economy is predicted to be the driver of not just the Asian but world economic growth over the next half a century.

The paper is organized as follows. Section 2 provides an overview of the testable implications of the second-generation models. Section 3 outlines data measurement issues. Graphical analysis and empirical tests of the theories using time series data from India is undertaken in Section 4. Micro-data is analyzed empirically in Section 5. Finally, several concluding remarks are provided in Section 6.

2. Testable Implications of Second Generation Growth Models

If we consider a homogenous CD production function as follows:

$$Y = AK^{\propto}L^{1-\propto} ,$$

Ha and Howitt (2007) have shown that growth rate of knowledge, g_A, is governed by the following equation,

$$g_A = \frac{\dot{A}}{A} = \lambda \left(\frac{X}{Q}\right)^{\sigma} A^{\phi-1} \quad \mathbf{1}$$

and

$$Q \; \alpha \; L^{\beta} \text{in steady state}$$

where X measures research input (based on semi-endogenous models) or the productivity-adjusted research input (based on Schumpeterian theory), Q is product variety, approximated either by income, employment or population (Aghion and Howitt, 1998), X/Q is research intensity, λ is the R&D productivity parameter, σ is a duplication parameter, assumed to be zero if all innovations are replication of existing knowledge and 1 if none of the new innovations is a replication, ϕ is returns to scale in knowledge and β is the coefficient of product proliferation. The semi-endogenous growth theory predicts that $\phi < 1$ and $\beta = 0$ and the Schumpeterian-growth theory posits $\phi = 1$ and $\beta = 1$. A log-linear transformation of Eq.1 is given as follows (Ha and Howitt, 2007):

$$Ln\left(\frac{\dot{A}_t}{A_t}\right) = Ln\lambda + \sigma\left[LnX_t - LnQ_t + \left(\frac{\phi-1}{\sigma}\right)LnA_t\right] + e_{1,t}\ , \quad \mathbf{2}$$

where $e_{1,t}$ are identically and normally distributed shocks with zero mean and constant variance. In the above equation, TFP growth, or the left-hand term should be stationary (Ha and Howitt, 2007; Zachariadis, 2003), because in steady state, TFP growth should be constant. Stationarity of the left-hand side of the above equation implies that the term in the square brackets of Eq.2, reproduced below should also be generated by a stationary process.

$$S = \left[LnX_t - LnQ_t + \left(\frac{\phi-1}{\sigma}\right)LnA_t\right] \quad \mathbf{3}$$

As Ha and Howitt (2007) point out, Eq.3 applies to both the semi-endogenous and Schumpeterian theories but with disparate parameter specifications. Specific co-integrating relationships should exist between the variables of Eq.3 as a test of the theories. These are summarized by the following two equations:

$$\upsilon_t = LnX_t + \left(\frac{\phi - 1}{\sigma}\right) LnA_t \quad \textbf{(Semi - endogenous growth theory)} \qquad \mathbf{4}$$

$$\varsigma_t = LnX_t - LnQ_t \quad \textbf{(Schumpeterian growth theory)} \qquad \mathbf{5}$$

The semi-endogenous theory (Eq.4) argues that there is no role of product variety and thus, it suggests that the log of X and log of A should be co-integrated with the second-element of the co-integrating vector being strictly negative, as ϕ is assumed to be less than 1 by these models. On the other hand, the Schumpeterian theory (Eq.5) assumes constant returns to knowledge and allows for product proliferation. Therefore, a test of these models would be to check if logs of X and Q were co-integrated with the second element of the co-integrating vector equal to -1.

Apart from co-integration tests, empirical estimations could also be carried out to test the predictions of the competing theories, as shown in Madsen (2008). Not only can these estimations complement tests based on the co-integration analysis, they can also be used to test for other factors influencing TFP growth of an economy. The three factors considered here are international technology spillovers, absorptive capacity and distance to frontier of these countries. The available empirical evidence suggests that each of these factors is responsible for promoting TFP growth of an economy. Savvides and Zachariadis (2005), and Coe and Helpman (1995) among others have shown using import-weighted R&D shares that technology embodied in imported goods promotes TFP growth. However, as Aghion *et al.* (2005) and Griffith *et al.* (2003, 2004) argue, a country needs to devote its own resources towards R&D to be able to learn from tacitly embodied knowledge developed elsewhere. They find evidence that these domestic R&D expenditures facilitate the absorptive capacity of an economy. Furthermore, Kneller (2005) and Griffith *et al.* (2003, 2004) suggest that knowledge transfer can, at times, occur autonomously without the requirement of such investments. This autonomous transfer takes place regardless of trade in goods or foreign direct investment as also pointed out in Aghion and Howitt (2006) and Jones (2002), and captures the idea of catching up or "conditional convergence".

Madsen (2008) is the first study to incorporate all these three factors explaining TFP growth while testing for second-generation R&D based models using long-historical data from OECD countries. He uses the following model which complements the co-integration models given above in Eq.4 and 5, to explain TFP growth:

$$\Delta LnA_t = \tau ln\left(\frac{X_t}{Q_t}\right) + \left(\frac{\sigma}{1-\phi}\right)\Delta LnX_t + \xi\left(\frac{A_{t-1}^{max} - A_{t-1}}{A_{t-1}^{max}}\right) + e_{3,t} \qquad \textbf{6}$$

where A^{max} is the global maximum TFP level, and measures the available "leading-edge technology". The relative difference in TFP of an economy from the global maximum captures the idea of "conditional convergence". The lag in this term allows TFP growth in the current period to respond to the distance from the frontier in the previous period. All other variables are as explained before. This equation states that TFP growth, the left-hand side variable, is a function of R&D intensity, growth in R&D and autonomous technology transfer. Madsen (2008) uses both domestic and foreign measures of research activity and research intensity and the foreign R&D intensity and growth in research activity weighted by a country's imports captures the idea of technology transfer. In Eq.6, the semi-endogenous growth theory would argue that $\tau = 0$ and $\sigma/1\text{-}\phi > 0$ whereas the Schumpeterian theory would argue that both $\tau > 0$ and $\xi > 0$.

3. Data and Measurement Issues

This study uses both aggregate- and firm-level data to test the theories. Aggregate time series data goes as far back as 1950. Various measures of research activity including R&D personnel, R&D expenditure, and patent data have been gathered from several publications of the Ministry of Science and Technology and World Intellectual Property Organization, respectively. This data still remain relatively unknown to researchers, and to the best of my knowledge, not used elsewhere thus far. The firm-level data covers the period 1993 to 2005 – when India started to devote increasing attention towards knowledge creation and when firm-entry was de-regulated. The following section explains the construction of variables used in the study, and their respective data sources.

TFP at the aggregate level is estimated using the following homogeneous Cobb-Douglas production function as follows,

$$TFP = \frac{Y_t}{K_t^{\propto}(HL)_t^{1-\propto}} \qquad \textbf{7}$$

In the above equation, Y is real GDP, K is the aggregate capital stock, H is an index of human capital; HL measures the quality adjusted workforce; and α measures capital elasticity. The assumption of constant returns to scale is maintained. TFP growth is calculated as one-year differences in the logs of TFP levels as follows:

$$TFPG_t = LnTFP_t - LnTFP_{t-1}$$

Output (Y) is taken to be the real gross domestic product valued at factor cost (net of taxes less subsidies), available from various Statements of the Indian National Accounts Statistics ("NAS" hereafter). The chosen base-year is 1999.

Capital stock (K) is taken to be the real value of fixed assets at 1999 prices. It is measured using the perpetual inventory method as follows,

$$K_{t+1} = K_t(1-\delta) + I_{t+1}$$

where δ is the depreciation rate and I_t is investment. The NAS provides information on Gross Fixed Capital Formation ("GFCF" hereafter) for two different types of capital, non-residential structures (construction) and non-residential machinery at current prices. Both these types of capital are deflated using appropriate deflators constructed by dividing total GFCF in current prices on both types of capital, by total GFCF at 1999 constant prices. A capital stock series constructed in this manner is superior to the one constructed using data only on aggregate gross fixed capital formation, as the former measure allows for different depreciation and growth rates for the two different types of capital. Moreover, the aggregate stock of capital obtained from the NAS also includes investments in residential buildings and machinery, which should not be included in TFP estimation. The initial capital stock for each type of capital is determined as follows

$$K_0 = \frac{I_0}{\delta + g}$$

which is standard methodology adopted in the literature (see e.g., Coe and Helpman, 1995). In the above equation, I_0 is the investment in physical capital in the initial period under consideration (taken to be the GFCF in that period), δ is defined as before, and g is the average geometric growth rate over the period 1950 to 2005. Depreciation rate is assumed to be 3 percent for non-residential structures and 10 percent for machinery. In the literature, the depreciation rate for construction is taken to be 3 percent as standard, although, that for machinery using data on developed countries is taken to be 17 percent (see e.g., Madsen, 2005). However, studies on India use a much lower depreciation rate for the aggregate capital stock reflecting its slower rate of replacement of old machinery (Virmani, 2004; Goldar, 2004).[2]

Data on the Indian labour force (L) is unavailable from the NAS because of the large informal industrial sector in India. Therefore, labour force data has been calculated using the Summer-Heston Dataset, Penn World Tables 6.2 as follows,

$$L = \frac{Real\ GDP\ per\ capita}{Population} * Real\ GDP\ per\ worker$$

The estimate of Real GDP per capita in the Penn world Tables is based upon the economically active population series available from the ILO. Unfortunately, data on hours-worked in India are unavailable from any source and therefore, labour force data is uncorrected for hours worked. However, piecemeal data on hours worked from the ILO suggests that it has varied from 43 to 48 hours per week across different economic activities but there is hardly any variation within each economic activity. Therefore, not correcting for hours worked is not likely to cause a major bias in TFP estimates. Labour's income share is assumed to be constant at 0.7 based on convention (Virmani 2004).

Human capital (H) is measured, as done in Hall and Jones (1999) for developing economies, assuming a piece-wise linear rate of return of 13.4 percent for the first four years of schooling and 10.1 percent for the subsequent four years,

$$H = (1 + r)^s$$

In the above equation, r is the average return to schooling, s is the average years of schooling, for population aged 25 and above, data on which is gathered form Barro and Lee (2001). This

[2] Besides a 10 percent depreciation rate for machinery used in this study, different rates of 5 percent and 15 percent were also considered. Results remained robust to these changes.

data is available at five-year intervals from 1961 to 2001 and has been interpolated and extrapolated for missing years using an exponential growth rate. Including human capital refines TFP estimates, because such capital is found to be a significant contributor to TFP growth for a cross-section of countries (Hall and Jones 1999).

Research activity is measured by R&D personnel (N), R&D expenditures (R&D) and patents. Data on the R&D based measures has been gathered from various publications on "R&D Statistics" of the Department of Science and Technology and Planning Commission (2007). To the best of my knowledge, no study has used both these data from India till date from 1950 onwards, as done here. Data on R&D expenditures is unavailable for a few years between 1950 and 1960, and data on R&D personnel is available only at ten year intervals between 1950 and 1990. Missing data has been interpolated using a geometric growth rate. Following Madsen (2008), nominal R&D expenditures have been deflated using an un-weighted average of the labour costs deflator and GDP deflator. Another deflator was also tried, which also considers the costs of capital goods, besides considering the labour input costs. This second R&D deflator is constructed using labour costs deflator (45%), GDP deflator (45%), equipment (5%) and structures (5%) deflator respectively, where the values in brackets signify weights. However, results remained robust to the choice of the deflator.

Patent activity is measured by patents granted to, and applied for, by domestic residents. This data is available from World Intellectual Property Organization WIPO (2007). One of the foremost advantages of using patent data as measures of scientific activity is that, they directly measure the research output (Madsen, 2008), and therefore, do not require any normalization when considering the Schumpeterian theory. However, the disadvantage of using patent data is that not all innovations are patented. Moreover, the average value of patents may change over time.

Product variety (Q) in Schumpeterian models is measured either by employment or GDP, as shown by Madsen (2008). Research intensity (X/Q) is measured as follows,

$$\left(\frac{X}{Q}\right)_A = \frac{N}{L}$$

$$\left(\frac{X}{Q}\right)_B = \frac{N}{AL}$$

$$\left(\frac{X}{Q}\right)_C = \frac{R\&D}{Y}$$ **8**

$$\left(\frac{X}{Q}\right)_D = \frac{R\&D}{AL}$$

$$\left(\frac{X}{Q}\right)_E = \frac{Pat}{L}$$

In the above equations, *A* is TFP, and *Pat* stands for Patent applications filed or Patents granted. All other variables are defined as before. Patents are not divided by A because as mentioned above, patents measure research output directly.

International technology spillovers are measured by an import-ratio weighting scheme as follows:

$$\left(\frac{X}{Q}\right)_{it}^{f} = \sum_{n} \frac{m_{ijt}}{m_{it}} \left(\frac{X}{Q}\right)_{jt}^{d} \quad , \qquad i \neq j$$

9

$$X_{it}^{f} = \sum_{n} \frac{m_{ijt}}{m_{it}} \bar{X}_{jt}^{d} \quad , \qquad i \neq j$$

where *d* and *f* stand for domestic and foreign respectively, *n* indexes India's import partners, m_{ij} is India's import of high-technology products from country j, m_i is India's total imports of high-technology imports, $\bar{X}$ is an index of research intensity, which takes on a value of 1 in 2000. This method of using an import-weighting scheme to measure transmission of technology through import of goods, is similar to that used in Coe and Helpman (1995) and exactly the same as used in Madsen (2008) and Savvides and Zachariadis (2005). The following SITC classifications are used for high-technology products: Chemicals and related products (SITC Section 5), Machinery and Transport Equipment (SITC Section 7), and Professional and scientific instruments (SITC Section 8.7).

All countries which have had a larger than 0.5 percent share in India's total imports over time are included in these estimates. Data on India's trading partners has been gathered from various publications of the International Monetary Fund and the United Nations. Data on the TFP level, employment and research intensity of India's trading partners is available from Madsen (2007b) except for that related to China and South Korea. These data have been collected from various official websites of these countries respectively. Data on imports by country and product category is available from UN Comtrade Database (2007). However, this information is only available from 1962 onwards. For the period 1950-1961, the trade value has been assumed to be the same as in 1962. Data on SITC 8.7 is available from 1978 onwards. For prior years, the value has been assumed to be the same as in 1978.

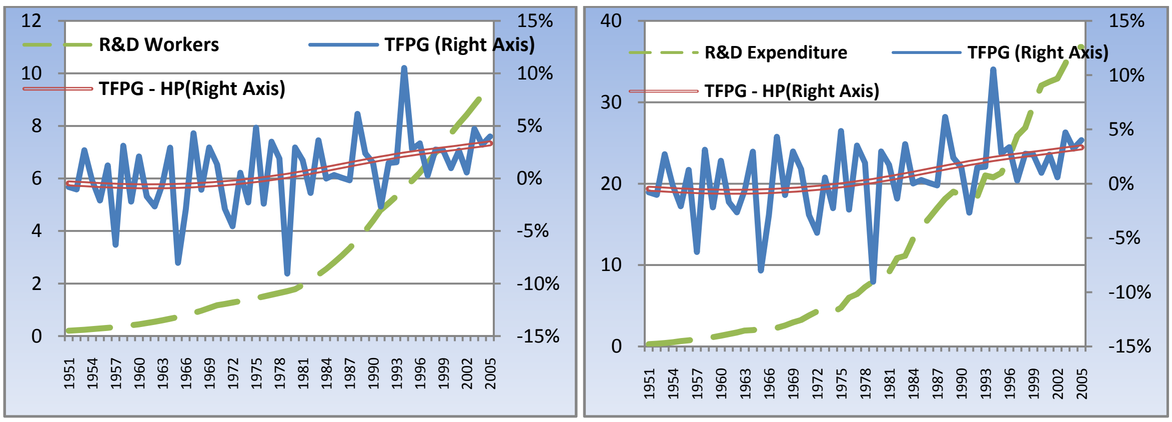
4. Time Series Evidence (1950-2005)

The following section uses graphical analysis, cointegration tests and empirical estimations to test whether the first- and second-generation growth theories are consistent with aggregate time series data from India.

4.1. Graphical Evidence

As pointed out before, the first-generation growth models suggest that TFP growth is equi-proportionally related to the level of resources devoted to R&D (either R&D personnel or real R&D expenditures). However, no empirical studies to date support the claim. Data gathered from India also does not find much support for this hypothesis.

Figure 1: TFP Growth and Resources Devoted to R&D

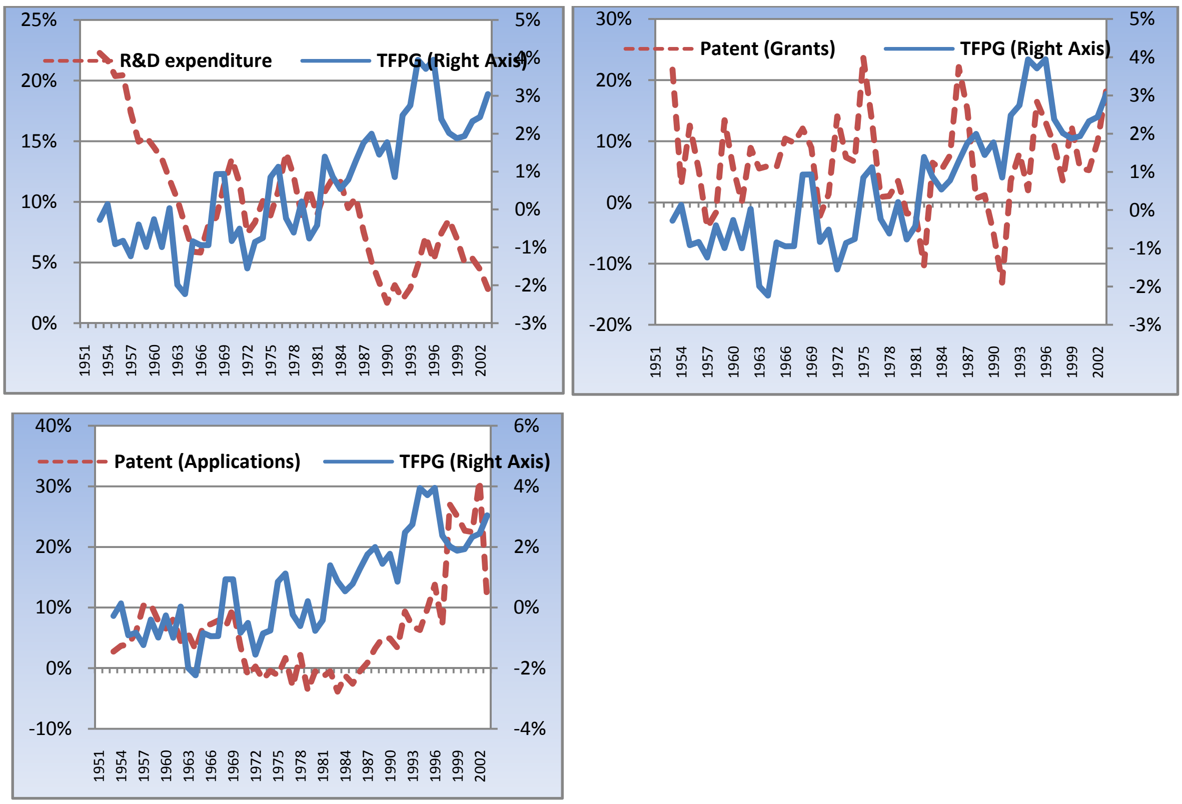


Note: "HP" stands for a Hodrick-Prescott filtered series. Real R&D expenditures are measured in Indian Rupees.

Figure 1 plots TFP growth, its Hedrick-Prescott filtered series, and the number of R&D personnel and real R&D expenditures. It is clear that both R&D personnel and real R&D expenditures have increased steadily over the period 1950 to 2005. In fact, they have increased by a factor of 150 and 50, respectively over this period. On the other hand, TFP growth displays only a modest upward trend from 1962 onwards. However, the growth of both R&D personnel and real R&D expenditures has far exceeded that of TFP. This is inconsistent with the assumption of constant returns to the level of resources devoted to R&D, maintained by these models.

The semi-endogenous growth theory predicts a positive relationship between the growth in research activity and TFP. Figure 2 shows TFP growth against the growth of real R&D expenditures, and both measures of patents used by this study. Real R&D expenditure has tended downward over the entire period, even though its growth is pro-cyclical with that of TFP growth. The growth of Patent (grants) is highly correlated with that of TFP growth, but growth of Patent (applications) and TFP growth are only weakly correlated. On the whole, this graphical evidence lends limited support to the semi-endogenous growth theory.

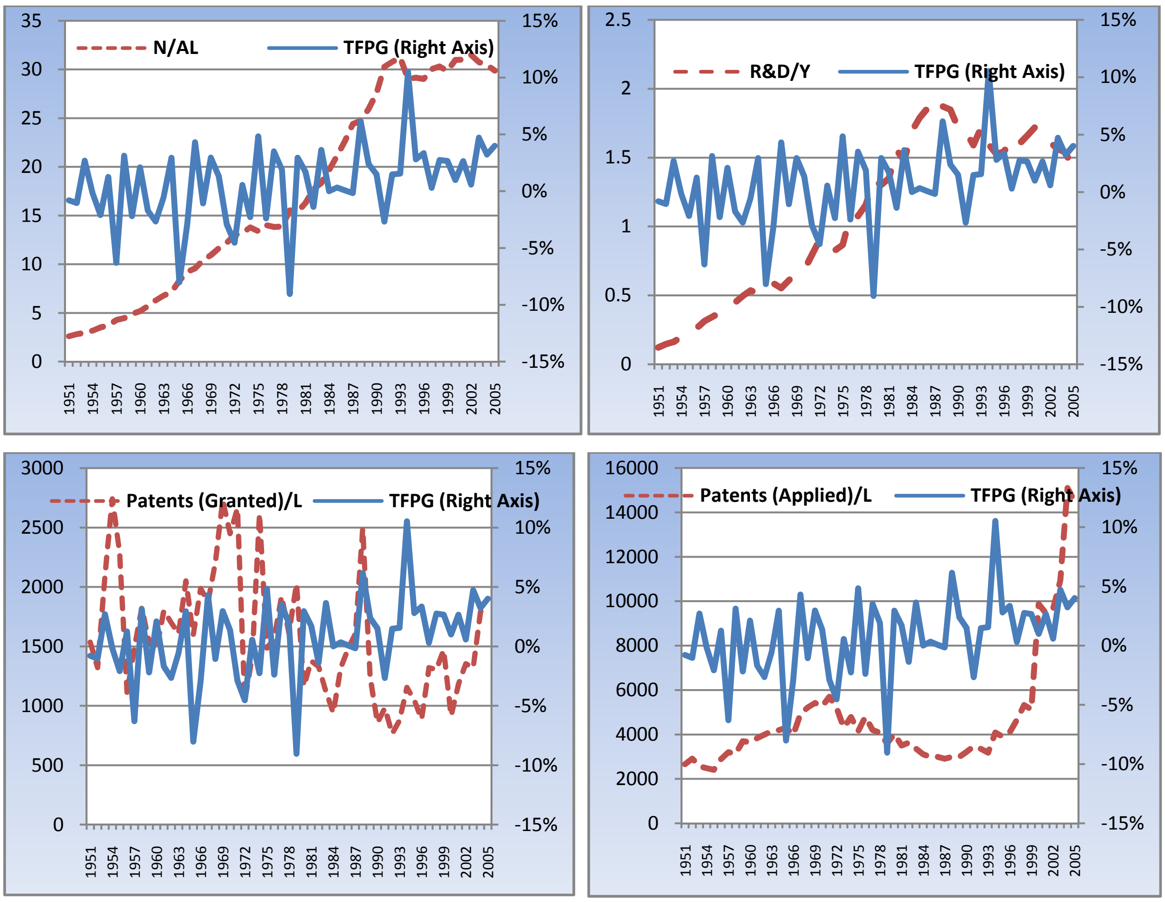
Figure 2: Growth in TFP and Research Activity



Note: Growth in TFP and all measures of research activity are based on 5-year centred moving average.

Finally, the Schumpeterian theory suggests that TFP growth is proportionally related to research intensity. Figure 3 below, shows TFP growth and various measures of research intensity. Notice that the R&D workers and real R&D expenditure based measures of research intensity increase steadily from 1950 until the late 1980s or early 1990s and either stagnate or decline thereafter. This is an interesting finding in the light of the economic reforms that were instituted in India during the late 1980s and gradually thereafter over the 1990s and 2000s. It was only over this period that regulations on new products and entry of firms were removed. Therefore, it is no surprise, that the data shows stagnancy or even a decline in measures of N/AL, R&D/Y and R&D/AL over this period. Each of these three measures of research intensity is proportionally related to TFP growth over the period 1950 onto the early 1990s over which these measures of research intensity have risen and TFP growth, although pro-cyclical, displays an upward trend. Thereafter, these measures of research intensity have stagnated or declined whereas TFP growth continues to remain pro-cyclical.

Figure 3: TFP Growth and Research Intensity



On the other hand, Patent (Grants)/L seems to move pro-cyclically with TFP growth throughout the whole period whereas Patent (Applications)/L does not seem to be correlated with it. Overall, this graphical evidence lends partial support to the Schumpeterian theory.

4.2. Cointegration tests

This section presents cointegration tests of the two competing theories. The two equations representing the cointegrating relationships for both theories are reproduced below.

$$\upsilon_t = LnX_t + \left(\frac{\phi - 1}{\sigma}\right) LnA_t \quad (\textbf{Semi}-\textbf{endogenous growth theory}) \qquad 4$$

$$\varsigma_t = LnX_t - LnQ_t \quad (\textbf{Schumpeterian growth theory}) \qquad 5$$

Eq.4 would be stationary if the log of TFP and log of R&D are integrated of the same order and If they are non-stationary, then they are co-integrated with a co-integrating vector $(1, \frac{\phi-1}{\sigma})$ in which the second element of the co-integrating vector is strictly negative (Ha and Howitt, 2007). Similarly, stationarity of Eq.5 can be established if the log of adjusted R&D inputs is stationary, or if the log of X and log of Q are co-integrated with a co-integrating vector (1,-1).

This paper has used various unit root tests including the Augmented Dickey-Fuller ("ADF" hereafter), Kwiatkowski Phillips Schmidt and Shin ("KPSS" hereafter), Phillips Perron ("PP" hereafter), Ng Perron ("NP" hereafter) and Zivot Andrews ("ZA" hereafter) test. This is because it is now reasonably well established that the ADF and PP tests are known to suffer from a finite sample power and size bias, especially when the macroeconomic series is short and has structural breaks (Campbell and Perron, 1991). In such a situation, it is better to use those tests, such as the KPSS, NP and ZA, which can account for a structural break in the data. It is remarkable to note that both Ha and Howitt (2007) and Laincz and Peretto (2006), have used only the ADF unit root test in their co-integration analysis. Results reported below in Table 1 are based on the NP and ZA statistics, even though the discussion highlights results based on all tests.[3] The last row in this table, for the benefit of the reader, also summarizes the test results for each of these variables.

Table 1: Unit-root Tests for Semi-Endogenous theory

	Test	TFP	N	R&D	Patents_G	Patents_A
Levels	NP	-0.108	-20.928	0.279	-19.580	-82.470
	ZA	-3.851	-2.907	-3.522	-6.096	-2.051
First Differences	NP	-26.923	-6.807	-20.510	-26.875	-1.805
	ZA	-9.457	-4.705	-6.627	-8.136	-10.818
RESULT		**I(1)**	**I(1)/I(2)**	**I(1)**	**I(0)**	**I(0)/I(1)**

Notes: N, R&D, Patents_G and Patents_A stand for R&D workers, real R&D expenditures, patents granted and patents applied for respectively. The null-hypothesis of all tests except the KPSS is the presence of a unit-root. The null hypothesis of the KPSS tests is that of stationarity. Constant and trend included in the test equation when examining variables in levels and constant but no trend included when examining variables in first-differences. Lag-selection in the NP test is based on the Schwartz Information Criterion (SIC). The spectral estimation method for the NP test is based on the AR-GLS method. The ZA test statistics are the minimum t-statistics. This test automatically selects a break-year in the data, not shown in the results. Critical values for the KPSS test are 0.739 and 0.463 at the 1% and 5% level respectively without inclusion of a trend and 0.216 and 0.146 at these significance levels when including a trend. Critical values for the NP test are -13.8 and -8.1 at the 1% and 5% level respectively without inclusion of a trend and -23.8 and -17.3 at these levels when including a trend. Critical values for the ZA-test are -5.43 and -4.8 at 1% and 5% respectively without inclusion of a time-trend and -5.57 and -5.08 at these levels including a trend.

Note that, as highlighted above in Section 2, both Eqs.4 and 5 pre-suppose that the log of TFP growth, $Ln\left(\frac{\dot{A}_t}{A_t}\right)$, is stationary in the long-run. Each test, including those not reported here, confirms this. Findings indicate that the log of TFP in levels has a unit root, whereas the log of TFP in first-differences (TFP growth) is stationary. This result is robust to inclusion or exclusion of a trend in the test equation.

Various measures of research activity are found to be either stationary, or integrated of order one or two. Consider first, the results for R&D personnel (N). Each and every test including the ones not reported here, except the KPSS, suggests that this variable has a unit root in both levels and first-differences. Therefore, it may not be I(1). On the other hand, each statistic including the ones not reported here, suggests that real R&D expenditures is I(1). As regards the patent based measures, each test statistic suggests that Patent (grants) is stationary in both levels and first-differences, which implies that it is I(0), whereas Patent (Applications) appears to be either I(0) or I(1) based on the NP and ZA statistics respectively. Other tests statistics not reported here also fail to provide an unambiguous answer to the

[3] Nearly all variables including TFP, various measures of research activity and research intensity, except for patent-based variables, appear to have a structural break. Further examination based on the Chow-test, suggests that most of the suggested variables have a plausibly strong break observed somewhere between 1980 and 1995.

order of integration of Patent (applications). Given that TFP and only some of the variables representing research activity - R&D, and perhaps, N and Patent (applications) - are I(1), the next step is to test for cointegration between TFP and these measures of research activity. Results of the Johansen co-integration test are presented in Table 2.

Table 2: Johansen Co-integration test for Verifying Semi-endogenous theory

Variables	Trace Statistic	Max Eigenvalue Statistic	Co-integrating Vector	
			First	Second
Log of TFP and Log of N	15.201	15.018	1.00	0.432
	(0.055)	(0.038)		[3.535]
Log of TFP and Log of R&D	25.384	24.905	1.00	0.832
	(0.001)	(0.001)		[0.477]
Log of TFP and Log of Patents_A	19.446	15.558	1.00	-0.013
	(0.012)	(0.031)		[0.272]

Notes: The null hypothesis of the test is that of no co-integrating relationship between the variables. Values in parenthesis are p-values. Values in square brackets are t-statistics. Lag-selection is based on the Akaike and Schwarz Information Criteria. Intercept but no Trend included in Cointegrating equation and Vector Autoregressive Model.

These results decisively reject the null hypothesis of no cointegrating relationship between TFP and R&D, as well as between TFP and Patent (Applications). However, no cointegrating relationship is found to exist between TFP and N. The important aspect to note here is that, in none of the three cases, the second element of the co-integrating vector found to be negative and significant. Therefore, although it can be stated that whereas two measures of research activity are cointegrated with TFP, these results do not provide support for the semi-endogenous theory. In fact, these results raise further doubts on the assumption of diminishing returns to knowledge, maintained by the semi-endogenous models.

Results of cointegration analysis of the Schumpeterian theory, (Eq.5) are presented in Table 3 and Table 4. The first table checks for stationarity of variables measuring research intensity in logs. As above, different unit root tests have been tried but the table reports only statistics based on the NP and ZA. Most tests statistics, including the ones not reported in Table 3 do not find any variable representing research intensity, except Patent (Grants)/L, to be stationary. All the variables are found to be either I(1) or even I(2). Therefore, the next step is to check for cointegration between different measures of logs of research activity (X) and product variety (Q). To conduct cointegration tests, one would need to verify if various measures of X and their corresponding measures of Q are integrated of the same order or not. Note that, it has already been shown in Table 1 that N is either I(1) or I(2), R&D is I(1) and

Patent (applications) is either I(0) or I(1). Results from various unit root tests not shown here, suggest that L is either I(1) or I(2), and that both Y and AL are I(1). Based on these findings, one can verify if the logs of N and L, R&D and Y, R&D and AL, and Patent (applications) and L are cointegrated or not. In this analysis, Patent (Grants) is not included as Patent (Grants)/L is already found to be stationary by the unit root tests reported above in Table 3**.**

Table 3: Unit Root Tests for Schumpeterian theory

	Test	N/L	N/AL	R&D/Y	R&D/A.L	Patents_G//L	Patents_A/L
Levels	NP	-15.686	-4.271	0.729	0.729	-19.164	-74.146
	ZA	-2.882	-1.530	-3.494	-3.320	-6.056	-2.090
First Differences	NP	-6.297	-10.353	-2.297	-2.637	-8.202	-1.737
	ZA	-5.094	-8.153	-4.011	-8.482	-8.121	-10.720
RESULT		**I(2)/I(1)**	**I(1)**	**I(1)/I(2)**	**I(1)**	**I(0)**	**I(0)/I(1)**

See notes to Table 1

Table 4: Johansen Co-integration Tests for Schumpeterian theory

Variables	Trace Statistic	Max Eigenvalue Statistic	Co-integrating Vector	
			First	Second
ln N and ln L	20.94 (0.007)	20.20 (0.005)	1.00	-3.539 (36.312)
Log of N and Log of AL	16.046 (0.041)	16.039 (0.026)	1.00	1.472 (1.400)
Log of R&D and Log of Y	27.43 (0.001)	24.47 (0.001)	1.00	0.699 (1.368)
Log of R&D and Log of AL	27.82 (0.000)	26.12 (0.000)	1.00	0.370 (0.549)
Log of Patents_A and Log of L	12.711 0.126	12.338 0.099	1.00	14.300 (3.470)

See notes to Table 2

Cointegration results based on the Johansen cointegration test are reported in Table 4. These results decisively reject the null of no cointegrating relationship between N and L, R&D and Y, R&D and AL, and also weakly reject the same null in the case of N and AL. However, there is no support of cointegration between Patent (applications) and L. In none of the cases, is the second element of the co-integrating vector found to be equal to -1. Albeit this is contrary to the prediction of the Schumpeterian theory, Madsen (2008) points out, that this reflects lack of a perfect representation of product variety by these variables. Therefore, that the second element of the cointegrating vector is not found to be negative is not strong enough evidence against the Schumpeterian theory. One can conclude from these cointegration tests that these results give plausible support for the Schumpeterian theory, except when considering the measure of Patent (applications).

4.3. Empirical Estimates

Following the discussion in Section 2, the following equation is estimated as done by Madsen (2008).

$$\Delta lnA_t = \gamma_0 + \gamma_1 \Delta lnX_t^d + \gamma_2 \Delta lnX_t^f + \gamma_3 ln\left(\frac{X}{Q}\right)_t^d + \gamma_4 ln\left(\frac{X}{Q}\right)_t^f + \gamma_5 Ln\left(\frac{A_{t-1}^{US}}{A_{t-1}^{IND}}\right) + \epsilon_{3,t} \qquad \textbf{10}$$

which tests both the second generation growth models while also allowing for international technology spillovers, distance to frontier and absorptive capacity. The semi-endogenous growth theory predicts that γ_1, $\gamma_2 > 0$ and γ_3, γ_4, $\gamma_5 = 0$ whereas the Schumpeterian theory predicts γ_3, γ_4, $\gamma_5 > 0$ and γ_1, $\gamma_2 = 0$. Growth of imports of foreign technology and import weighted research intensity variables, which are measured by the third and fifth right-hand side terms in each of these equations capture the international technology spillovers. The ratio of the TFP level of the US to that of India measures the distance to frontier. The main findings reported here do not include a measure of absorptive capacity which is measured as the interaction term between distance to the frontier and domestic research intensity. This is because, it is found to be highly correlated with domestic research intensity which leads to a negative and insignificant coefficient on both absorptive capacity and research intensity in nearly all estimates, which were tried. Therefore, it was considered prudent not to report them here. However, this is no way undermines the role of absorptive capacity in promoting TFP growth.

Note that “distance to frontier” has been measured here using the relative gap of India’s TFP to the US, rather than the global-maximum. The rationale for using this measure is two-fold. First, the highest TFP level is that of Ireland and Japan. It is unlikely that the TFP level of Ireland affected TFP growth in India. Secondly, the US has remained a dominant trading partner of India right from the 1950s and is the bastion of knowledge creation.[4] Note

[4] Regressions were also tried by measuring DTF as the relative TFP distance from the global-maximum, however, results remained robust to this change.

also that data on R&D personnel is unavailable for India's trading partner. Therefore, the estimates presented here use only R&D expenditure and patent based measures of research intensity.

Eq.10 is estimated using the Dynamic Ordinary Least Squares ("DOLS" hereafter) estimator proposed by Stock and Watson (1993). This method uses first differences of one-period lags of the dependant and independent variables, as well as first differences of one-period leads of all I(1) variables. Specifying these additional variables captures the dynamic path around the long-run equilibrium. The equation is estimated in 1- 5- and 10-year differences. The rationale for choosing higher order differences is to reduce the effect of transitional dynamics on TFP growth. The research intensity variables are taken to be the average over all years covered by the differences. Distance to frontier and absorptive capacity are evaluated at the beginning of the period over which the differences are taken. All estimations use Newey-West robust standard errors. Results shown here pertain only to 10-year differences. Estimates based on 1- and 5-year differences do not add much value to the analysis, however they corroborate the findings reported here.

Table 5: Empirical Estimates of Eq.10 in 10-year Differences

	R&D/Y		R&D/AL		Pat_G/L		Pat_A/L	
$\Delta \ln X^d$	0.221	(2.424)	0.136	(1.452)	0.023	(0.545)	0.129	(2.425)
$\Delta \ln X^f$	0.079	(1.947)	0.053	(1.142)	0.058	(2.519)	0.097	(1.484)
$(X/Q)^d$	0.219	(3.963)	0.118	(5.142)	-0.513	(9.196)	-0.042	(1.319)
$(X/Q)^f$	0.119	(2.659)	0.183	(4.808)	0.115	(3.098)	0.356	(3.658)
DTF	-0.239	(2.503)	-0.255	(4.282)	0.032	(0.191)	1.039	(8.989)
LM-1	0.535	[0.464]	1.377	[0.241]	18.627	[0.000]	4.958	[0.026]
LM-2	5.155	[0.076]	6.206	[0.045]	18.821	[0.000]	5.118	[0.077]
R^2	0.88		0.98		0.92		0.97	
Normality	1.067	[0.586]	1.606	[0.447]	0.861	[0.649]	1.121	[0.570]
No. of obs.	44		44		44		44	

Notes: DTF is Distance to frontier. LM is the Breusch-Godfrey LM statistic, which tests the null hypothesis of no serial-correlation in the residuals. LM-1 tests serial correlation with one lag in the data and LM-2 tests serial correlation with two lags in the data. Normality test is based on the Jacque-Bera test statistic which tests the null hypothesis of normality of residuals. Values in parenthesis are t statistics. Values in square brackets are p-values. Robust NeweyWest standard errors have been used.

Consider first, estimates related to the semi-endogenous growth theory. The coefficient on growth of domestic research activity is economically and statistically significant in half of the cases. These results corroborate the evidence of cointegration tests provided above in Section 4.2, which suggest that TFP is cointegrated with both R&D and Patent (applications).

The coefficient on growth in imports of technology achieves statistical significance at conventional levels in only half of the cases. This does not provide much support for international technology transfer through growth in imports and in turn to the semi-endogenous theory. However, this finding is not surprising given the highly restrictive trade- and industrial-regime of India until 1991, under which, imports of capital- and intermediate-goods were controlled by a licensing system, and imports were only allowed if it could be proven that domestic production of the same products was inexistent. Furthermore, workers of developing economies need to be adequately skilled to be able to assimilate the tacit technology embodied in these imports (Savvides and Zachariadis, 2005). If workers in these countries are not skilled enough, which is certainly the case in India (Hall and Jones, 1999), harnessing the information embodied in imported technology could turn out to be a long drawn affair.

Turning to the Schumpeterian theory, one can observe that the support for this theory exists only when using the R&D based measures of research intensity. Patent based measures of research intensity do not provide any support to this theory. On the other hand, there is strong support that research intensity weighted imports of technology have had a significant positive economic impact on TFP growth in India. This result is similar to that of Savvides and Zachariadis (2005), who also found research intensity weighted imports of technology positively affecting TFP growth of developing countries. This finding supports the Schumpeterian theory, which argues that TFP growth is related to research intensity, regardless of the source of such innovations (Madsen, 2008). Overall, these results provide plausible if not convincing support for the Schumpeterian theory.

It is striking to note that foreign research intensity has had a much more magnified impact on TFP growth compared to domestic research intensity in India, which only suggests that domestic conditions in India – barriers to entry of firms and products – did not ensue in heavy product proliferation, the basic foundation on which the Schumpeterian models rely. To substantiate this claim, regressions were estimated over the truncated period from 1950 to 1991 – a period over which expansions of varieties of products and free entry of firms was not allowed in India. Results are not shown here to save space, although suffice to note that coefficients on domestic research intensity were found to be either insignificant or negative and weakly significant in all estimates

Turning to the findings related to "Distance to frontier", estimates fail to find an unambiguous answer in support of either convergence or divergence. In all cases when R&D data is used to measure research intensity, the coefficient on DTF is found to be negative, and mostly significant. On the other hand, when patent data is used, the coefficient on DTF is found to be positive and significant, when patents are measured by patents applied for. To explain the negative coefficient on DTF, one could turn to the argument made by Aghion *et al.* (2005), that a country needs to have achieved a critical level of financial development and worker skill level, to be able to converge to a higher growth trajectory. Using a sample of 71 countries over the period 1960 to 1995, they do not find conditions in India conducive enough to be able to converge to the frontier growth rate. Therefore, whereas results from this research do not point convincingly in the direction of either convergence or divergence, empirical evidence provided elsewhere argues that necessary conditions which promote convergence, may not be present in India's case.

This concludes the evidence based on aggregate time series data from India. Table 6 summarizes the evidence for the two theories based on graphical, cointegration and empirical analysis. As can be observed, the analysis supports both the semi-endogenous and Schumpeterian theory to a limited extent, even though cointegration analysis seems to provide strong support for the Schumpeterian models and no support for the semi-endogenous models. In this sense, these findings are not entirely in contrast to those of Madsen (2008) and Ha and Howitt (2007), who find little support for the semi-endogenous models and plausible support for the Schumpeterian models, as well as those of Zachariadis (2003, 2004), who find strong support for the Schumpeterian models. However, it must be borne in mind that the first forty years for which aggregate data is available were characterized by the absence of two indispensable assumptions of these second-generation theories, namely, knowledge creation and free entry of firms. Therefore, lack of support for the semi-endogenous theory based on cointegration analysis and only limited support for the Schumpeterian theory based on the graphical and empirical analysis may be reflective of this. As a measure of further analysis of these theories, the next section considers how both these theories perform when using longitudinal firm-level data.

Table 6: Summary of results using Aggregate Indian Data

	Semi-Endogenous Theory	Schumpeterian Theory
Graphical Analysis	Limited Support (pro-cyclical with real R&D expenditures and Patents Granted)	Limited Support
Cointegration Analysis	No Support	Plausible Support
Empirical Analysis	Limited Support (Only in half the estimates)	Limited Support (Only in half the estimates based on domestic research intensity)

5. Firm-level Panel Data Evidence (1993-2005)

Firm-level data is available from 1993 onwards and is a useful complement to the results presented above for a number of reasons. This is because, over the period 1993-2005, knowledge creation was being given increasing importance and there was steady reduction in barriers to entry of new firms including foreign firms. Moreover, innovations are primarily attributable to the firm and using data at the micro-level would provide deeper insights into the analytics of both these theories, and shed more light on the assumptions that these theories maintain.

The only literature on second-generation growth models using firm-level analysis is the study by Laincz and Peretto (2006). However, they use only time series properties of their data without running panel regressions, which would provide more information. The present study uses both the cross sectional variation and time series elements of the available data. Furthermore, this study also captures the effects of distance to industry technology frontier and absorptive capacity in explaining TFP growth of firms, not done in Laincz and Peretto (2006). Though, note that data used in this study is available only for a relatively short period, which by no means could be termed as a period of stable long-run equilibrium, given the short time-span and more importantly, because of the structural adjustment programme that the Indian Government initiated in 1991. Therefore, a rich set of time- and industry-dummies are included in the regressions to minimize the effects of transitional dynamics. A balanced panel is used consisting of 126 firms, for which R&D expenditure data was positive for each and every year over this period.

TFP at the micro-level is measured as follows

$$TFP_{it} = \frac{Y_{it}}{K_{it}^{1-\alpha_1-\alpha_2} L_{it}^{\alpha_1} M_{it}^{\alpha_2}}$$

where Y is the deflated value of output of a firm at 1993 prices, K is the capital stock constructed as the aggregate of equipment stock and structures, L is labour force, M is deflated value of material consumption; α_1 and α_2 are the factor-shares of labour and materials respectively, and i and t index a firm and time period respectively. The assumption of constant returns to inputs is maintained. Factor shares have been calculated as the ratio of factor incomes to total output in current prices. All these variables have been gathered from an electronic firm-level data source, called *Prowess*, available from the Centre for Monitoring Indian Economy, Mumbai. The procedure of deflation of variables is outlined in Saxena (2007). Data on patents, R&D personnel, and imports by source is unavailable at the firm-level.

The analysis in this section closely follows the chronology adopted above. Results of panel co-integration tests are shown first to confirm stationarity of variables, after which follows the empirical analysis.

5.1. Panel Unit Root Tests

This section presents results of panel unit root tests of Eq.4 and 5, reproduced below, while keeping in mind that the following results relate to panel-data.

$$\upsilon_t = LnX_t + \left(\frac{\phi - 1}{\sigma}\right) LnA_t \qquad (\textbf{Semi}-\textbf{endogenous growth theory})$$

$$\varsigma_t = LnX_t - LnQ_t \qquad (\textbf{Schumpeterian growth theory})$$

Although this dataset has a short time dimension in absolute terms, as also relative to the cross section dimension (T=12 and N=126), this does not either obviate the need for panel unit root tests or bias these results. Conducting panel unit root tests is now common using panels of such nature (see e.g., Hall and Mairesse, 2005; Im *et al.*, 2003). As with aggregate time series data, several panel unit root tests were tried including the Im, Pesaran and Shin ("IPS" hereafter), Augmented Dickey Fuller Maddala Wu ("ADF" hereafter), Breitung and

Hadri tests, but tests results from only the Breitung tests statistics are reported in Table 7. Other tests are not reported here because Hlouskova and Wagner (2006) find using Monte-Carlo simulations, that the ADF test displays unsatisfactory size behaviour in case of short panels (T=10,20), as well as in the presence of serially correlated errors. On the other hand, the Breitung test maintains its robustness in both these situations. They also suggest that the Hadri statistic is weak in the presence of serial correlation. Baltagi and Kao (2000) find unsatisfactory size-adjusted power properties of the IPS. This evidence seems to suggest that the Breitung test performs best in the case of short panels and serial correlation. Therefore, emphasis is placed on the Breitung test statistic, according to which, each and every variable displayed in Table 7 is I(1). Note also that the test statistics, including the ones not reported here, suggest that TFP in first-differences is found to be stationary which is a pre-requisite for the stationarity check of both Eq.4 and 5.

Table 7: Breitung Panel Unit-Root Tests (Semi-Endogenous and Schumpeterian theories)

	A	X	Q		X/Q	
Variable	TFP	R&D	Y	AL	R&D/Y	R&D/AL
Levels	1.700 (0.955)	-1.055 (0.146)	-1.192 (0.117)	-0.494 (0.311)	0.717 (0.763)	-1.076 (0.141)
First Differences	-10.669 (0.000)	-10.585 (0.000)	-7.957 (0.000)	-12.566 (0.000)	-10.789 (0.000)	-11.049 (0.000)
RESULT	**I(1)**	**I(1)**	**I(1)**	**I(1)**	**I(1)**	**I(1)**

Notes: The null-hypothesis of the Breitung panel unit root test is the presence of a unit-root. Lag-selection is based in the Schwartz Information Criterion (SIC). Values in parenthesis are p-values. All test equations include a constant and a trend.

The next step is to perform panel co-integration tests to verify if the log of TFP and R&D are co-integrated (semi-endogenous theory), and whether the log of R&D and Y and R&D and AL are co-integrated (Schumpeterian theory). Results of co-integration tests are presented below in Table 8 based on Pedroni (2004). Note that Pedroni (2004) had pointed out that in small samples (T=20), the Group-panel ADF test statistic performs best. Consider first, the cointegrating relationship between log of TFP and R&D (semi-endogenous theory). Whereas the panel statistics accept the null of no cointegration, the group panel statistics accepts that at least one of the panels in the cross-section displays a cointegrating relationship. This implies that data pertaining to not all, but only a few firms conforms to the hypothesis of this theory. However, the second element of the cointegrating vector is found to be positive and insignificant. Although this is not evidence in stark contrast to the theory, it does not support its predictions either.

On the other hand, consider results of cointegration between the log of R&D with that of log of Y and AL. Both the panel and group-panel statistics decisively reject the presence of no cointegrating equations in these variables. Note also that the second element of the cointegrating vector between log of R&D and Y is sufficiently close to -1, and significant, which gives strong support to the Schumpeterian theory. In the case of log of R&D and AL, this element is negative and significant, although smaller compared to -1.

Table 8: Pedroni Panel Co-integration Tests
(Semi-Endogenous and Schumpeterian theories)

Variables		Panel Statistics		Group Panel Statistics		Co-integrating Vector	
						First	Second
Log of R&D and log of TFP	PP Statistic	-0.764	(0.298)	-5.962	(0.000)	1.00	0.250
	ADF Statistic	-0.076	(0.398)	-4.080	(0.000)		[1.770]
log of R&D and log of Y	PP Statistic	-8.471	(0.000)	-10.913	(0.000)	1.00	-1.030
	ADF Statistic	-7.902	(0.000)	-8.685	(0.000)		[5.270]
log of R&D and log of AL	PP Statistic	-9.957	(0.000)	-11.729	(0.000)	1.00	-1.430
	ADF Statistic	-9.314	(0.000)	-6.548	(0.000)		(6.690)

Notes: The null of the test is of no co-integration. Panel statistics assume the same first-order auto-regressive term across all panels, while the group panel statistics assume different first-order auto-regressive term across panels. Values in parenthesis are p-values. Values in square brackets are t-statistics. A constant but no trend is included in the test equation. Variance and rho statistics not reported here.

The next section presents results of empirical tests to corroborate the results based on panel unit root tests and to understand factors explaining TFP growth at the firm-level.

5.2. Empirical Estimates

The following equation is estimated using longitudinal data.

$$\Delta lnA_{ijt} = \varphi_0 + \varphi_1 \Delta lnX_t^d + \varphi_2 ln\left(\frac{X}{Q}\right)_t^d + \varphi_3 ln\left(\frac{A_{ijt-2}^{max_j}}{A_{ijt-2}}\right) + \varphi_4\left(\frac{X}{Q}\right)_t^d ln\left(\frac{A_{ijt-2}^{max_j}}{A_{ijt-2}}\right) + C_{ijt} + \epsilon_{3,t} \qquad 11$$

In the above equations, *i, j* and *t* index the firm, the 2-digit industry to which the firm belongs; and time period respectively. *C* is a vector of control variables including time- and industry-dummies. These control variables are essential, as they capture macroeconomic shocks to all firms. Moreover, as explained above, the time series dimension of the available data is not long enough to capture long-run growth aspects and not including these control variables might lead to transitional dynamics blurring the relationship of the variables in the data. A^{max}_j measures the industry technology frontier. Distance to the industry frontier (autonomous technology transfer) is measured here as the difference in TFP of a firm of the j^{th} industry relative to the firm within that industry included in this balanced data sample, which has the highest TFP (A^{max}_j). The motivation behind choosing the highest-TFP firm of the industry from only within this chosen sample of firms, rather than from all firms of the industry, is that the theory of autonomous technology transfer pre-supposes that higher TFP is a result of higher R&D expenditure, and knowledge flows from these high TFP firms at the frontier to low TFP firms. Note that only the chosen firms in this sample have continually invested in R&D over the entire period, and hence, the rationale of choosing the highest TFP firms from only within this sample of firms.[5] Note though, that this is not the ideal measure of distance to the frontier, as suggested by Griffith *et al.* (2003, 2004), according to whom we should consider DTF as the difference in TFP from the global maximum. However, data on the global maximum TFP is unavailable. The measure used here is the available second best.

Both these equations are estimated using fixed effects OLS and system GMM dynamic panel data estimations in 1-year differences. Estimates reported in Table 9 are based on the GMM. However, note that, to minimize the effect of transitional dynamics, distance to industry frontier and absorptive capacity has been lagged by an additional year.

Notice first, the results for growth of domestic research activity. It is not found to purport TFP growth. The coefficient in both cases bears a negative sign but is not significant in one case and only weakly significant in the other. This finding gives no support to the semi-endogenous theory. On the other hand, there is reasonable, if not convincing support for the Schumpeterian theory. The coefficient on domestic research intensity when measured as R&D/Y is found to be economically and statistically significant. Notice that the co-integration tests also found convincing support for this theory, when considering research intensity based on this measure. However, when research intensity is based on R&D/AL, the results do not support the theory. These results bear semblance to those of Laincz and Peretto

[5] As a robustness check, distance to the frontier is also measured as difference in TFP relative to the highest-TFP firm in the industry, regardless of whether this firm is a part of the balanced-dataset or not. Results remain robust to this change.

(2006), who also fail to find any support for the semi-endogenous theory, while supporting the Schumpeterian theory using micro-level data.

Table 9: Empirical Estimates of Eq.**11** using System GMM

	GMM			
	R&D/Y		R&D/AL	
$\Delta\ A_{t-1}$	-0.227	(2.010)	-0.177	(2.730)
$\Delta\ \ln X^d$	-0.070	(1.810)	-0.033	(1.560)
$\ln\ (X/Q)^d$	0.111	(1.670)	-0.040	(3.070)
DTF	0.114	(2.770)	0.096	(2.390)
CDTF	0.218	(0.790)	0.000	(2.060)
No of obs.	1209		1209	
m(2)	[0.651]		[0.238]	
Hansen	[1.000]		[1.000]	

Notes: Robust standard-errors are used in all regressions. Variables are as defined before. Time- and industry-dummies included in all regressions. m(2) is the test for AR(2) in first-differences. The null hypothesis of the Hansen test is that all instruments are valid. Values in parenthesis are z-statistics. Values in square brackets are p-values. DTF is distance to industry frontier. CDTF measures absorptive capacity and is the interaction term between research intensity and absorptive capacity

As regards distance to the industry frontier and absorptive capacity, the results provide convincing argument in favour of both these arguments. That firms have the option to exit the industry makes the significance of the coefficient on DTF an interesting finding. It suggests that firms choose to persist in the industry and close the relative gap in productivity levels rather than exit. One of the primary reasons of resistance to exit would perhaps be resources committed to R&D. The role of absorptive capacity is also found significant.

This leads one to believe that the joint significance of these findings is that not only is it important for a firm to increase its R&D spending, but also its research intensity and investing in more complex innovations, in order to assimilate the technology developed elsewhere and close the gap of its own TFP relative to the firm with the highest TFP. Therefore, these results have significant implications for a firm's survival and success, as also for an economy's industries. These findings indicate that although intensifying R&D growth is essential, it is not sufficient for long term growth. What is needed is that R&D spending keeps pace with the increasing complexity of product varieties available in the economy.

6. Concluding Remarks

The present study uses national- and firm-level data from a developing and reforming economy – India - to test the predictions of second-generation growth theories. In doing so, this study sheds light on the implications of these models for a developing economy, considering little was known till date, on the applicability of these models for such economies. Furthermore, the empirical analysis offers more insights into the growth process of such economies, by studying the effects of international technology transfers, absorptive capacity and distance to frontier.

Aggregate time series data seems to be compatible with both theories, but only to a limited extent. Results based on graphical and cointegration tests find limited or no support for the semi-endogenous theories, even though the empirical analysis provides a fair degree of support for this theory. On the other hand, evidence gives plausible support in favour of the Schumpeterian theory based on cointegration tests and empirical analysis. Firm-level data provides support only for the Schumpeterian theory with no support for the semi-endogenous theory. Nonetheless, both aggregate and micro-level data corroborate the arguments in favour of convergence and absorptive capacity, even though, support for convergence is not strong, when using aggregate data.

These results question a key assumption of the semi-endogenous models, namely that of decreasing returns to R&D. Considering that several developing economies are not at the forefront of research, it is plausible to argue in favour of constant, if not increasing returns to knowledge generation in these economies, given that they enjoy a huge pool of knowledge stock developed elsewhere by advanced economies. Madsen (2007a) has also questioned this critical assumption and finds results supporting his argument using data from OECD economies. Moreover, Ulku (2007) suggests that returns to knowledge creation are in fact double for developing economies as compared to advanced economies. Therefore, further evidence is required on this subject of returns to R&D for developing economies. The empirical analysis also shows that the Schumpeterian theory is critically dependent on the assumption of free entry of firms and products.

Based on these results, can we make any inferences on the long-run growth prospects of similar developing economies and is there a basis to believe that these economies will ever catch up to the frontier? The answer depends on the pace at which frontier economies develop new technologies and non-frontier economies assimilate this knowledge. More precisely, frontier countries will keep discovering new ideas but theory suggests that the pace of these discoveries will slow down over time. On the other hand, countries that lie behind the frontier have the advantage of using the ideas developed elsewhere and advance towards the frontier. However, in order to do that, these countries need to achieve a threshold level of investments in human capital and financial development. Moreover, the process of catch up is also subject to diminishing returns over time. Therefore, it remains to be seen whether the process of discovering new ideas in advanced economies slows down faster relative to the process of catch-up by developing economies or the other way round. If the former holds, then there is a possibility that developing economies may catch up to the frontier, or else, shall forever trail.

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