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Is the Elephant Stepping on its Trunk?
The Problem of India's Unbalanced Growth

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Abstract

It is often assumed that recent success in the high-technology software industry will lead India's development. However, evidence suggest that basic manufacturing industry is stagnant. This paper proposes a mechanism that ties these two trends together. A big-push type of model, featuring linkages between firms, demand spill-over, and technology choice is elaborated. By imposing different cost structures on the manufacturing and high-technology industries the model describes outcome in terms of distribution between sectors. It is found that a policy which promotes a high-technology sector can have negative effects on the manufacturing industry as well as aggregate income. Directing resources towards infrastructure, on the other hand, benefits all sectors and increases aggregate income. The results from the model are found to correspond with the recent development pattern in India.

Keywords: L16, O14, O25
JEL classification: Industrialization, India, Industrial Structure

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1 Introduction

This study explores economic growth due to spill-overs between sectors in light of the empirical regularity that has become known as the stages of development. According to this regularity a country passes through three distinct stages on its way to becoming developed. In the transition from the first to the second stage the agricultural sector's share of aggregate income decreases while the manufacturing share increases. The transition from the second to the third stage entails a decline in the share of manufacturing in aggregate income and an expanding service sector.

The vast majority of countries that have a successful record of development have followed this pattern. Our study focuses on a country which stands on the brink of commencing an overarching economic development. At the beginning of the 21st century India became one of the fastest growing economies in the world. In accordance with the general pattern outlined above, the share of agriculture decreased. However, this was due to an expanding service sector rather than an expanding manufacturing sector. Moreover, a substantial part of the growth in services emanates from a fast growing high-technology information industry which is modern even by western standards.

In this sense, it seems as if India is skipping a whole stage of development. Is it possible for a country to successfully sidestep the general pattern of development stages? We analyze this question by asking to what extent the success in the service sector can lead an economy-wide progress that includes the manufacturing industries. A number of circumstances seem to point in favour of such spill-over effects. Profits and wage incomes from successful firms create a demand for other products. Advances in technology and production methods could be used to make manufacturing processes more efficient. Moreover, leading high-tech firms show success stories and provide role-models for others to follow.

Our intention is not to deny the validity of the above mentioned mechanisms. However, we believe that there are other factors that may dampen these effects. The reasons for these doubts are that, from a perspective of development stages, what happens at one stage gears the economy towards further development. The transition from an agricultural to a manufacturing economy creates a demand for investment in basic infrastructure such as railways, roads, harbors and communication systems. But it is likely that service industries, and especially high-technology industries, do not have the same needs. In this respect, a success in the service industry does not necessarily facilitate growth in manufacturing. Another case in point is the education system where an expansion of the first and second tier can be viewed as a response to the demands of an manufacturing industry. However, a high-technology sector primarily demands labor with tertiary education. For a country such as India, where the first and second tiers of education are badly in need of more resources, this creates a problem which also encompasses the prospects of manufacturing industries. Another argument concerns the consequences of service industries acting as subcontractors to manufacturing industries. If the service industry does not have a corresponding demand for manufacturing products, positive effects on manufacturing due to demand spill-over will be weaker. All these factors point to the possibility that the success of the information technology industry comes at the expense of other sectors, or at least that beneficial spill-over effects are less pronounced.

The aim of this paper is first to map out the situation in India and to frame the problem in a suitable theoretical approach. Second, we elaborate a model to describe what we believe to be a central mechanism in this development. In some simple policy experiments we try to demonstrate that a policy directed at promoting a high technology service sector has negative growth implications. However, in this static setting we also find that there is an optimal level of government involvement.

The paper is organized as follows. Section 2 describes the recent development of the Indian economy with regards to manufacturing and high technology services. In section 3 we frame our problem and discuss related research. Section 4 develops and solves the model. In section 5 and 6 the results are discussed and put in context. Section 7 concludes.

2 India's growth experience

From 1960 to 2003 India's growth in real per capita GDP was stagnant at about 2.5 percent per annum, giving rise to ideas about a Hindu-rate of growth. After the reforms of 1991 the average growth rate (up to 2003) was above 3.5 percent increase in per capita GDP. The trend in recent years has been an accelerating growth at 6 percent or higher.[1]

Over the long period real output from both manufacturing and services has increased, the former with a factor 6 and the latter with a factor 8, suggesting a service led growth. However, the wide aggregate of services hides a very diverse set of activities.[2] From here on we will focus on the high-

[1] The growth rate in per capita GDP for 2005 was 7.75 according to figures from *World Development Indicators*.

[2] Services has for a long time had an unproportional share in India's industrial structure (Hansda, 2002). The implications of this have been debated since independence. We maintain that the implications of high-technology services growth can be analyzed

technology segment of the service industry. This is the type of production which fits best into the development-stage framework since it bears evidence on India's move into the third stage.

2.1 High-technology service industries

The recent boom in the Indian information technology (IT) industry has spurred hopes that the stagnant growth pattern can be broken (e.g. Srinivasan, 2004). In their study of the 'revolution' in services Gordon and Gupta (2004) put business services, a category which includes IT, at the top of their list of fast growing service sectors. According to NASSCOM, the Indian National Association of Software and Service Companies, information technology and information technology enabled services increased their share of GDP from 1.9 percent in 1999/2000 to a projected share of 4.8 percent in 2006.[3] Although activities are increasingly geared towards more advanced services, it should be noted that a large portion of the firms are still call-centers, back-offices and the like. However, what is important for our purposes is the fact that in a developing country such as India a modern, high-technological industry plays an increasingly important role.

An educational system that favors higher education, and a resulting large reserve of scientists and engineers, stands out among the proposed explanations for India's success in the IT industry (Arora and Athreye, 2002). Other reasons commonly mentioned are facilitating policies from the government, preferential labor market and import/export regulation and foreign connections in the form of a large diaspora (see Kapur, 2002, for a typical exposition). Considering India's poor infrastructure, it is also important that the physical infrastructure needed for IT is more easily clustered. The establishment of Software Technology Parks, where firms are provided with communication facilities, spread all over India, is evidence of government involvement and of the feasibility of clustering.

2.2 Manufacturing

Kochhar *et al.* (2006) document disappointing tendencies in the development of Indian manufacturing. The manufacturing sector, with the exception of some industries demanding high-skilled labor, is lagging behind the recent growth trend. In view of India's enormous pool of low-skilled labor, this is a puzzling fact. Figure 1 gives an illustration of this disappointing growth in

independently of this historical fact.

[3] *Factsheets* published on http://www.nasscom.in/

Indian manufacturing. The solid line shows a 5-year moving average of the growth rate in Indian manufacturing, the dotted line shows the corresponding per capita values. A crude sketch of the post independence (1947) Indian history can be made by a three-fold division (Kaushik, 1997). First there was an initial push towards industrialization following independence, during the rule of Jawaharlal Nehru.[4] Then, quasi-socialist policies became a burden, and the overly controlled economy was stagnant up until the decade before the famous reforms of 1991.[5] In the 1980s industrialization gained momentum and there were several years of sustained high growth. But, as can be seen from figure 1, India has not managed to maintain this high level of growth.

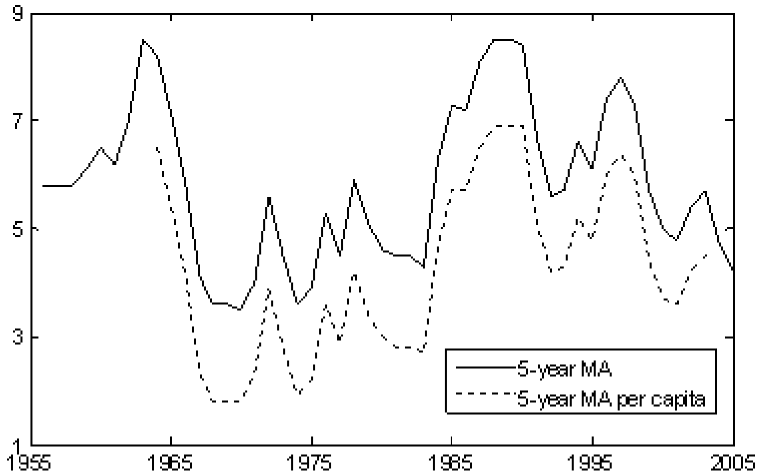

Figure 1: Growth in India's Manufacturing Output

3 Framing the problem

Our hypothesis is that the developments in the high-tech sector and the manufacturing sector are causally related. In one sense, this is trivially true. As we have seen, government policies have favored the growth of a high-tech service sector both through long term policies regarding education and recently also through more directed policy measures. But why did this success not

[4]For a discussion of the so called Mahalanobis plan see Nurkse (1957).

[5]The fact that growth started to accelerate years before the reforms were enacted is analyzed in Rodrik and Subramanian (2004).

spill over to the manufacturing sector? Why has an increased economic activity not generated growth in the low-end manufacturing sectors? Here, India with its vast pool of unskilled labor appears to have an obvious comparative advantage.

Our argument is not that there is something worrying about the strong development of high-technology services *per se*. However, there are plausible causal mechanisms that tie this positive development to the less convincing performance of the manufacturing sector.[6,7]

1. It is commonly recognized that investment in infrastructure is badly needed in India (Tonkin *et al.* 2006). There are several reasons why it is easier for a high-technology service firm than for a manufacturing firm to handle these shortcomings. First of all, investment in telecommunications and fast speed computer communication are less costly than hard infrastructure such as roads and railways (Kapur, 2002). As for electricity supply, special regulation allowed information technology industries to build their own generating capacity (Arora and Athreye, 2002). Secondly, the infrastructure required for production of services can more easily be clustered thereby lowering fixed costs. In view of the success of the service industry there is a risk that resources are channelled away from the kind of infrastructure that would further the development of a manufacturing industry. The argument here is that the success of the service industry tends to reduce political pressure for overall infrastructural investments, or at least channel it in other directions.

2. Reforms of education are not being undertaken. One of the prime explanations for India's success in information technology is the great reserve of qualified engineers. It is a well known fact that India has always had a relatively well endowed and well functioning educational system at the tertiary level. However, it is also well known that this has come at the expense of primary and (especially) secondary education

[6] Some researchers, e.g. Gordon and Gupta (2004), tend to interpret the data differently. They see the current stagnation in industry and the fast growing service sector as evidence that India has reached the third stage of development. However, considering that India's per capita GDP is about 2 percent of OECD average, we argue that it can hardly be maintained that India has reached an industrialized stage of development. In this regard, it can also be mentioned that in 1995 agriculture employed about 2/3 of the workforce.

[7] The notion that underdeveloped economies might skip technological steps taken by previously industrialized economies has been given the label "leapfrogging" in the literature. The prototypical example is when a country goes from having no telephones into using mobile phones (Stough *et al.* 2005).

(Rao *et al.*, 2003).[8] An increased demand for higher education from service sectors could potentially cement this malignant pattern.[9] The argument here is that the poor quality of the primary and secondary schools hurt manufacturing the most by lowering the productivity of the workforce in that sector (Bosworth and Collins, 2007).

3. There are fewer and less strong backward linkages from service sectors to manufacturing sectors than in the other direction. This means that service industries have less need to buy intermediate inputs from other industries (outside the service sector) than manufacturing industries. The linkages in the Indian economy have been studied by Banga and Goldar (2005) and Hansda (2002). Although they find evidence of linkages in both directions, Hansda stresses that backward linkages from the service sector are weaker than the forward linkages (sales to other sectors). If the service sector is not generating a demand elsewhere in the economy then it will not increase market potential of manufacturing goods.

A predominant idea in the structuralist framework, which we will subscribe to in this study, is that what happens at one stage of development can be said to prepare, or lay the foundation for, subsequent development. At an abstract level, this is the essence of the problems above.[10] For instance, during the development phase where manufacturing expands, physical infrastructure is built up, partly as a response to demand from producers.

Export demand is an obvious explanation for the emergence and much of the subsequent growth in the IT sector, which we disregard from in our model. Based on demand for exports it could still be argued that the high tech service sector will continue to develop independently of manufacturing. In this regard, it is our contention that such pattern is highly unlikely to

[8] One indication of this pattern comes from literacy rates. Bosworth and Collins (2007) report literacy rates (ages 15-24) of 76 percent in India compared to 99 percent in China.

[9] Some studies have indicated that primary and secondary schooling are more important propellants of growth than higher education (Self, 2004). Other find that secondary education is the key education variable in explaining growth convergence between Indian states (Trivedi, 2002). However, in general there is little consensus regarding the relationship between education and growth (Temple, 2001).

[10] The explanation for the poor performance in manufacturing proposed by Kochar *et al.* (2006) is that increases in labor cost are spilling over to manufacturing industry. Although intensive in low-skilled labor lower end manufacturing also has a need to employ more qualified staff such as managers, administrative personnel and production engineers. Hence, increased wage cost for high-skilled labor also hurt the competetiveness of manufacturing. This a price-effect that we will abstract from in our analysis.

sustain growth in the long run. In a country the size of India's, domestic demand is arguably crucial.[11]

It is instructing to compare India with South Korea, which is one of the prime examples of successful export led growth (Westpahl, 1990). Korean industrial policy in the 1960s primarily focused on facilitating growth of internationally competitive export industries. A wide array of policies, from tax exemption to direct intervention, was implemented. Importantly, the protection also comprised domestic production of intermediaries used in the production of export goods. Similarly to India, external demand was a key in Korea's accelerated growth. What separates the two cases is the way that this demand spilled over into other sectors. In this respect it is arguably critical that Korea managed to secure complete production chains.

Another problem in our study is how growth in manufacturing can be achieved. It is our contention that manufacturing is not suffering from absence of comparative advantage in relation to the high tech sector. A more appropriate view is that of a bottleneck problem involving high fixed costs. Our model captures these costs in terms of underdeveloped infrastructure. However, equally important explanations can arguably be found in the labor regulations, high import and export tariff and other institutional constraints that remains even after the deregulation wave starting in 1991 (Kohli, 2006; Ahluwalia, 2002). Our model abstracts from differential effects due to regulation on growth in manufacturing and high-tech services.

3.1 Related Research

Three distinct strands of theory dealing with the industrialization process can be discerned. The most recent is the new economic geography/trade theory. Monopolistic competition models with transport costs are used to show that once a certain critical mass, in the form of either technological or pecuniary externalities, has been reached an agglomeration process starts (Krugman, 1981; Krugman and Venables, 1995; Markusen, 1989). In a multilateral trade setting, countries can differ with respect to stage of development due to varying transport costs (Baldwin *et al.*, 2001).[12]

Second, in the traditional neoclassical capital accumulation theory, the key components are capital and technology. A country develops through accumulation of physical and human capital. Due to diminishing marginal productivity of capital, growth eventually comes to a halt where only technological progress can generate further growth (Solow, 1956). Later research

[11] A similar argument is presented by Wu (2007).

[12] A recent study is McLaren (2000) who shows that industrial structure is closely linked to the openness of an economy.

has integrated technological choice to show the possibility of different levels of industrialization (e.g. Parente and Prescott, 1994; Zilibotti, 1995).[13]

The third strand of theory, which we believe to be most relevant to our problem, is the structuralist branch (Chenery, 1975). An early study is Kuznets (1957), who concluded that the long term trends in the industrial structure of a growing economy were remarkably similar to the cross section differences between countries with different per capita income. It is now common practice to associate the stages of development with the sectoral divide between agriculture, manufacturing and services (Rostow, 1971).

Kuznet's conclusion was that economic development is associated with an increase in the share of manufacturing and a decline in the share of agriculture. However, the development of the service sector was considered less clear cut (see Chenery, 1960). A more modern account of development stages includes a step where manufacturing stagnates and services grow (Kongsamut, *et al.*, 2001).

Another common ingredient of the structuralist tradition is the emphasis on linkages between sectors (Hirschman, 1958) and chains of input and demand spill-over (Rosenstein-Rodan, 1943). The modern and formal interpretation of these arguments is 'Increasing returns' or 'Big Push' models.[14] The study by Murphy *et al.* (1989) has been influential for the rather small literature that combines increasing returns with linkages between different producers. The basic idea is that firms can choose to implement an increasing returns technology. Fixed cost associated with this mode of production is prohibitively expensive for the individual firm. Murphy *et al.* (1989) demonstrated that an adoption of the new technology was possible only by coordinating the implementation across many sectors. The demand spill-over due to higher total output then helps more firms to overcome the fixed cost.

Fafchamps and Helms (1996) analyze vertical linkages between intermediate inputs. They show that intermediate input demand combined with a high income elasticity for industrial goods can generate multiple equilibria. In a similar framework, Gans (1997; 1998a,b) discusses the fixed cost assumption. Fixed costs can enter either as overhead labor cost or as a deduction from output. Gans (1997) shows that the choice of specification is not crucial for generating multiple equilibria. The most recent contribution to this literature is Ciccone (2002). His model features horizontal intermediate demand

[13] For instance Rioja (1999) and Esfhani and Ramírez (2003) incorporate infrastructure as a public good to demonstrate the existence of an optimal level of infrastructural investment.

[14] Describing industrialization specifically as adoption of increasing returns to scale production has been an influential idea (e.g. Young, 1928; for a survey see Matsuyama, 1995)

linkages between industrial firms. From a technical point of view this is also our main source of inspiration.

In the next section, we build a model using the structuralist framework as developed by Ciccone (2002). Central to our analysis is how firms adopt different kinds of technologies, and how this is affected by interconnections between sectors. To make the analysis tractable we simplify other aspects of the economic environment. The most stark contrast to neoclassical models is that we will reduce the role of the price mechanism.

4 A model of industrialization

4.1 Outline of the model

The model has three sectors, denoted **A**(griculture), **M**(anufacturing) and **H**(igh technology). We will refer to **M** and **H** collectively as industrial sectors. Firms in these sectors are characterized by monopolistic competition, increasing returns to scale and the use of intermediates. **A** firms, also referred to as pre-industrial firms, have a constant returns to scale technology and use only labor as input.

We set up the model in three steps. First we follow Ciccone (2002) closely and build a model with only the two sectors **A** and **M**. We do this to show that it is possible to construct an equilibrium where some but not all firms have industrialized. In a second step, we allow different industrial technologies, i.e. we add the **H** sector. Finally, we introduce a government in order to study the effects of different policies.

Goods and firms are defined on a segment of the real line. Hence, there is a continuum of goods, each indexed by the real number $m \in [0, 1]$. If $m' < m''$, we say that m' is upstream of m''.

The first model generates an outcome where the n firms furthest upstream industrialize, i.e. are **M** firms. The other $1 - n$ remain in the pre-industrial stage, i.e. are **A** firms (figure 2). An industrial firm buys input from each industrial firm upstream (firm $m' \leq n$ buys from all $m < m'$).

In the extended model with two industrial sectors, the **H** sector lies on the interval $\left[0, n^H\right]$, the **M** sector on the interval $(n^H, n^M]$, and the **A** sector on $(n^M, 1]$ (figure 3). Again, an industrial firm uses input from all other firms upstream of its own position, i.e. **M** firms buy from both **M** and **H** firms, whereas **H** firms only buy from other **H** firms.

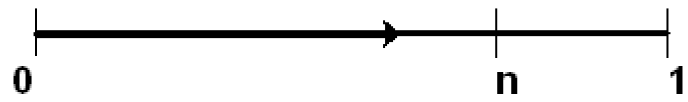

Figure 2: Structure with one industrial sector

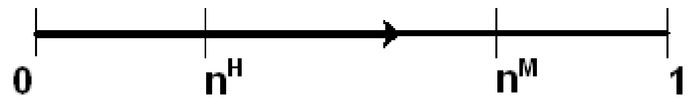

Figure 3: Structure with two industrial sectors

4.2 Basics

There is a measure L of households. The utility function of the representative household is specified as

$$U(c) = \int_0^1 \ln c(m) dm.$$

Where $c(m)$ is consumption of good m. Preferences over consumption goods are symmetric and the elasticity of substitution between different goods is unity. Assuming identical prices, households consume an identical amount of each good. On the supply side, each household inelastically supplies one unit of labor. Labor is the only resource and wages the only compensation to production factors. Apart from wages, households get additional income from firm's profit. Firms in the **A** sector produce one unit of output using one unit of labor. Hence, marginal cost of production is equal to wage. **A** firms are assumed to be perfectly competitive.

The industrial firm indexed m (either **M** or **H**) assembles a composite $z(m)$ of other industrial goods. In a second step, this composite is used together with labor to produce an intermediate good $x(m)$.

$$\ln z(m) = \ln m + \frac{1}{m} \int_{i=0}^{m} \ln x(i,m) di \tag{1}$$

$$\ln x(m) = \ln B + \beta \ln z(m) + (1-\beta) \ln l(m) \tag{2}$$

The aggregation function (6) is designed to have constant returns in x and to increase in m.[15] The production function (2), has a standard Cobb-Douglas form. The parameter $\beta \in (0,1)$ determines the relative factor shares of $z(m)$ and $l(m)$, and will be referred to as intermediate intensity input in industrial firms. The constant B is set so as to normalize the marginal product.[16] As a consequence, all firms have the same marginal cost. Set wage as numeraire ($w = 1$), to get unit marginal cost for all firms.

The final output $y_O(m)$ is produced using the intermediate good $x(m)$,

$$y_O(m) = \frac{1}{\theta} x(m) - f(m). \tag{3}$$

Where $\theta \in (0,1)$ is an technology efficiency parameter. The function $f(m)$ is a fixed cost, which is assumed to be increasing, $f'(m) > 0$. We use a first degree polynomial to describe this cost.[17] In the first model, with only **M** as industrial firms, the constant terms is omitted, and we have $f(m) = \phi m$.

Industrialization is described as a process in which **A** firms are replaced by **M** firms. This has two main effects. First, production is carried out more efficiently, due to the parameter θ. Second, the structure of production changes, as firms are linked together by intermediate input usage. The density of these interconnections is governed by the parameter β. For each good, the criterion for adopting the industrial technology by changing from **A** to **M** will ultimately depend on the demand for a firm's output, its fixed costs and the efficiency parameter θ. Since fixed costs are increasing in m, the further

[15] Dividing the integral by m ensures that we have CRS. And adding the logarithm of m yields a log-linear increase of $z(m)$ in m. If identical amounts (x^*) of each intermediate is used we have $z(m) = mx^*$.

[16] Equal marginal products of $z(m)$ and $l(m)$ gives $z(m) = \frac{\beta}{1-\beta} l(m)$. Substitute this into (2) to get $x(m) = B \left(\frac{\beta}{1-\beta}\right)^{\beta} l(m)$, which is solved for $l(m) = \frac{x(m)}{B} \left(\frac{\beta}{1-\beta}\right)^{-\beta}$ Under identical prices $w = p = 1$, the cost of $x(m)$ can be expressed as $Cost = l(m) + z(m) = l(m)\left(1 + \frac{\beta}{1-\beta}\right)$. Substitute $l(m)$ for $x(m)$ to get $Cost = \frac{x(m)}{B\beta^{\beta}(1-\beta)^{1-\beta}}$. Now we can set B so as to get a denominator equal to 1. This implies unit marginal and average cost of $x(m)$.

[17] Ciccone (2002) assumed constant fixed costs. Given this formulation once the first firm industrialized all others will follow. This follows from an increasing demand when more firms industrialize.

downstream the higher the cost of adopting the industrial technology. The rationale for this assumption, which will be discussed in more detail in section 5.1, is that coordination costs are higher when more intermediates must be shipped from different suppliers. The parameter ϕ will be interpreted as a cost which is dependent on the quality of infrastructure.

4.3 Profit and Demand

The perfectly competitive **A** firms set price equal to 1. We add the assumption that the markup of an industrial good has an upper cap. Each good can potentially be produced by **A**, **M** or **H** firms. If a monopolistic **M** or **H** firm sets its price above 1, it is assumed that an **A** firm enters and undercuts this price. Hence, the **A** firms constitutes a competitive fringe.

Technology and preferences imply that industrial firms face unit elasticity of demand from consumers and intermediate input buyers. Hence, industrial firms maximize profit by setting as high price as possible, and thereby reach the upper price bound. Consequently, the price of labor, intermediate input and consumption goods from all types of firms is equal to one ($p = 1$).

Given these prices, we can use final output (3) to write the profit function of industrial firms as

$$\pi(m) = y_O(m) - x(m) = (1-\theta)y_O(m) - \theta f(m). \tag{4}$$

Let $y_D(m,n)$ denote the total demand for good m when n firms have industrialized. Since monopolistic industrial firms make profit on each unit sold, it will always meet demand, $y_O(m) = y_D(m,n)$.

Demand has two components, demand for consumption and intermediate input. Given that prices are identical, only demand for intermediate input will differ between goods. Denote consumption demand, given that n firms have industrialized $D(n)$. Demand for good m as an intermediate input can be written as the sum of demand from all industrial firms downstream of m. The total demand for input for an industrial firm is $\theta\,[y_O(m) + f(m)]$, from final output (3). A fraction β of this is intermediate input. Moreover, the firm indexed m supplies intermediate input to a natural number m firms downstream.[18] Hence, a firm supplies $1/m$ of its total intermediate supply to each downstream industrial firm. Given this, the demand for good m as intermediate input can be expressed as

$$y_D(m,n) = \int_0^m \frac{\beta}{i}\theta\left(y_D(i,n) + f(i)\right) di + D(n). \tag{5}$$

[18]Technically, n and m are measures, this causes conceptual problems which we ignore. For details we refer to Ciccone (2002).

Consumers spend all their income on consumer goods, therefore $D(n)$ must be related to aggregate income, which we denote by $Y(n)$. Given identical prices, and a unit elasticity of substitution, households will buy identical number of all goods. Therefore $D(n) = Y(n)$.

$$y_D(m,n) = Y(n)\left(\frac{n}{m}\right)^{\theta\beta} + \left[\phi n \frac{\theta\beta}{\theta\beta+1}\left(\frac{n}{m}\right)^{\theta\beta} + \frac{m\phi}{\theta\beta+1}\right] - m\phi. \qquad (6)$$

The two parts within square brackets is the demand for m to cover fixed costs upstream.[19] Although firms incur a reduction in demand to cover its own fixed costs, demand is increasing in ϕ,[20] holding the level of industrialization constant. However, raising the fixed costs will move the frontier of industrialization upstream since fewer firms will now industrialize. This will cause demand for goods upstream as intermediates to decrease, and aggregate profits and income to fall.

Aggregate income is the sum of two components, labor income and profits from industrial firms. Due to inelastic labor supply and since the wage equal to 1, the former is equal to the exogenous L. We denote profits from industrialized firms by Π. From profit (4) and demand (6), the expression for aggregate profits is

$$\Pi = \int_0^n \left((1-\theta)\, y_D(m,n) - \theta f(m)\right) dm. \qquad (7)$$

Given the identity $Y(n) = L + \Pi$, demand (6) and aggregate profit (7) we can solve for aggregate income as a function of the degree of industrialization,

$$Y(n) = \frac{\left(L - n\lambda\frac{\phi n}{2}\right)}{n\lambda + (1-n)}. \qquad (8)$$

Where $\lambda = \left(\frac{1-\beta}{\frac{1}{\theta}-\beta}\right) < 1$. Note that we can divide by L to get a per capita expression. Aggregate income, and profits are all increasing in β and decreasing in θ.[21] If the intensity of intermediate input use or the efficiency increases (θ decreases), demand and profits will respond positively.

[19] To see this formally let $\hat{x}$ be the required output to cover fixed costs, then

$$\frac{d\hat{x}}{dm} = -\frac{\theta\beta\hat{x}}{m} + \phi.$$

When solved with initial condition $\hat{x}(n) = \phi n$ this yields the expression within the square brackets. Also note that we have to subtract the fixed costs in sector m from the demand for good m.

[20] $\frac{\partial y(m,n)}{\partial \phi} = \frac{\theta\beta}{(1+\theta\beta)}\left(n\left(\frac{n}{m}\right)^{\theta\beta} - m\right)$ and since $n > m$ this is allways > 0.

[21] This can be verfied using the fact that $\frac{\partial\lambda}{\partial\beta} < 0$ and $\frac{\partial\lambda}{\partial\theta} > 0$.

4.4 Equilibrium with two sectors

When analyzing the equilibrium, we use the concept of local stability.[22] An interior point $n \in (0,1)$, will constitute an equilibrium if firms upstream of n make a profit using industrial technology, whereas firms downstream would incur a loss.[23] We are only interested in cases where some, but not all firms have undergone industrialization. This restriction follows from our ambition to construct a model which allows us to analyze changes in sector shares due to policy interventions; positive changes in these shares would of course be impossible if all firms had industrialized to begin with.

Production of the marginal good, n, must generate the same profit whether produced by an **A** or an **M** firm.[24] Since **A** firms are perfectly competitive and make zero profit, the same must be true for an **M** firms. By the profit function (4) we thus have:

$$y(n,n) = \frac{\theta\phi n}{(1-\theta)} \tag{9}$$

We solve for the relationship between fixed cost parameter ϕ as a function of n. In condition (9), note that $y(n,n) = Y(n)$, and then substitute for $Y(n)$ using aggregate income (8). We then get an expression which can be solved for $\phi(n)$.

$$\phi(n) = \frac{2L(1-\theta)}{n^2[\theta\lambda + \lambda - 2\theta] + 2n\theta}$$

Note that $\frac{\partial\phi(n)}{\partial n} < 0$, i.e. the requisite fixed cost parameter decreases when we allow industrialization to progress further. Since $\phi(n)$ is decreasing in n we can get a lower bound for the fixed cost parameter by setting $n = 1$. For some parameters θ and β we can pick a $\phi^*(\theta, \beta, L, n)$ such that $n < 1$. Then our conditions are met and we have a stable equilibrium in point n. This demonstrates that a partial industrialization outcome can be a locally stable equilibrium.

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[22] For an rigorous analysis we refer to Ciccone (2002) and Krugman (1991).

[23] We here depart from Ciccone (2002), who analyzes three possible cases, pre-, full- and partial- industrial equilibrium. Since two former pertain to the big-push argument they have no relevance for our purposes.

[24] It is here assumed that a presumptive M firm does not internalize the effect of an expansion in demand due to his entry. There is a possibility that $\frac{d\pi(n)}{dn}|_{n=n^*} = (1-\theta)Y'(n^*) - \theta\phi > 0$, given that we allow $Y'(n^*) \neq 0$. It can be shown that this will always hold as long as $\beta < \theta$.

4.5 Introducing choice of technology

We now introduce a new structure, with two types of industrial firms **M** and **H**. These firms differ with respect to technology and fixed cost structure. An industrial firm can produce the final good using a parameter θ_M which costs nothing or at a cost c use a more efficient technology θ_H, such that $0 \leq \theta_H \leq \theta_M \leq 1$. Since demand, and hence profit, is declining in m, the firms furthest upstream will profit the most by using the more efficient technology. This will generate an outcome where **M** firms use intermediate input from both **M** and **H** firms, whereas **H** firms use only goods produced by other **H** firms. The **H** sector will therefore be the interval $0 \leq m \leq n_H$, and the **M** sector the interval $n_H < m \leq n_M$.

4.6 Demand and profit functions

Begin with the **M** sector. As before we can find the demand for **M** goods by solving for $y_D(m, n_M)$. The demand facing firms in the interval $n_H < m \leq n_M$ is given by two parts. One is the demand from other **M** firms, and the other consumption demand. This can be expressed similar as in (5). For firms $m \in (n_H, n_M]$:

$$y_D(m, n_H, n_M) = \int_{n^H}^{m} \frac{\beta}{i} \theta_M \left(y_D(i, n_M) + f_M(i)\right) di + Y(n_M, n_H) \tag{10}$$

Where $f_M(m) = \phi m$. And the total consumption demand $Y(n_H, n_M)$ is now dependent on the size of both the **M** and the **H** sector. For the **H** firms in the interval $0 \leq m \leq n_H$, demand can again be expressed as three components. Of these, demand from **M** firms and consumer can be summarized in one component which is equal to the demand facing the **M** firm furthest upstream. This is $y_D(n_H, n_M)$, which can be derived from (10). The third part is the demand from other **H** firms, which obviously also must lie in the interval $0 \leq m \leq n_H$. For firms $m \in [0, n_H]$:

$$y_D(m, n_H, n_M) = \int_{0}^{m} \frac{\beta}{i} \theta_H \left(y_D(i, n_H, n_M) + f_H(i)\right) di + y_D(n_H, n_M). \tag{11}$$

Where $f_H(m) = c + \phi m$. Given demand in each sector, we can find the industrialized firm's profit. Integrating over the two sectors yield aggregate profits Π^H and Π^M. Aggregate income will consist of three parts, profits from the **H** and **M** sectors, income from labor:

$$Y(n_M, n_H) = \Pi^M + \Pi^H + L. \tag{12}$$

Generally, aggregate profit can be written as

$$\Pi^M + \Pi^H = Y(n_M, n_H)A(\beta, \theta_M, \theta_H, n_H, n_M) + \phi B(\beta, \theta_M, \theta_H, n_H, n_M).$$

This can be substituted into aggregate income (12) and solved for $Y(n_M, n_H)$. Since A and B are nonlinear functions in most parameters, we only present numerical solutions.

4.7 Equilibrium with three sectors

The equilibrium of interest is one where the **H** sector has begun to develop but still not engulfed the **M** sector. Put formally this means that $n_M \in (0,1)$ and $n_H < n_M$. As before the **M** firm furthest downstream, is indifferent to industrializing. In other words, this firm makes zero profits, yielding the condition:

$$(1-\theta_M)y(n_M, n_M) - \theta_M f_M(n_M) = 0. \tag{13}$$

With two industrialized sectors, the **M** firm furthest upstream, i.e. closest to the **H** sector, must be indifferent to switching to the **H** technology. From the profit function (4) we get the following condition:

$$(\theta_H - \theta_M)y(n_H, n_M) + \theta_H f_H(n_H) - \theta_M f_M(n_M) = 0. \tag{14}$$

4.8 Policy Experiments

We now introduce a government in order to perform policy experiments. The government redistributes from aggregate income to either the **M** or the **H** sector. The revenue side of the government is a uniform flat tax on each households income. The expenditure side is a subsidy which lowers the fixed costs. The magnitude of government involvement is exogenously given.

A first experiment is to subsidize the cost of using the **H** technology θ_H. We introduce a subsidy τ, and each **H** firm now pays a fixed cost $f_{H,G1}(m) = (1-\tau)c + \phi m$. Denote the total cost of this subsidy G. This gives us two restrictions, which together with condition (13), characterize the equilibrium:

$$(\theta_H - \theta_M)y(n_H, n_M) + \theta_H f_{H,G1}(n_H) - \theta_M f_M(n_M) = 0. \tag{15}$$

and

$$G = \tau c n_H.$$

A second experiment is to subsidize the cost ϕm, which is common to all industrialized firms. Again the size of the subsidy is given by a share τ of the fixed costs. Hence **M** firms now have a cost $f_{M,G2}(m) = (1-\tau)\phi m$, and **H** firms $f_{H,G2}(m) = c + (1-\tau)\phi m$. We have the conditions

$$(1-\theta_M)y(n_M, n_M) - \theta_M f_{M,G2}(m) = 0 \tag{16}$$

$$(\theta_H - \theta_M)y(n_H, n_M) + \theta_H f_{H,G2}(n_H) - \theta_M f_{M,G2}(m) = 0. \tag{17}$$

And the budget constraint for the policy maker is

$$G = \tau \int_0^{n_M} \phi m dm.$$

5 Results

5.1 Conceptual issues and Parameter values

The full model has three sectors, which differ with respect to (i) fixed costs, (ii) level of returns to scale, (iii) use of intermediates and (iv) supplies of intermediate goods to other firms.

The model features two types of fixed costs. The first pertains to the use of industrial technologies (**M** or **H**). These modes of production requires the use and combination of different intermediate inputs. The fixed cost captured by ϕ reflects the cost of coordination, which is increasing in the number of intermediates used. This provides the conceptual link to infrastructure. It is plausible that poor infrastructure is more costly as more intermediate goods have to be shipped geographically across the country and more contacts are needed between buyers and suppliers. The second cost is the cost of upgrading the industrial technology. This cost should be thought of mainly as an investment in human capital and skills needed to adopt the **H** technology.

Both of these costs are incurred at the firm level in order to make industrial production feasible. Here it is important to underscore that our model is designed to analyze a development economy, where there are substantial costs associated with low quality infrastructure and low levels of human capital. These costs must be covered in order for a production unit to establish. The empirical task of identifying these costs is by no means straight forward, but in principle they are observable entities. In solving the model, we will in practice treat these costs as residuals. The costs are set so as to achieve the desired distribution of sectors. Given the other parameters, ϕ and c will determine the size of **H** and **M**.

In our model it might seem counterintuitive that **H** has a higher degree of returns to scale than **M**. If the latter represents manufacturing we usually think of these firms as the prototype for increasing returns – especially processing of raw materials. However, the firms in our model has no degrees of freedom in making an output volume decision, but merely responds to a given demand. This means that a shift from the **M** to the **H** technology should be interpreted as a decision to shift to a more efficient technology rather than a decision pertaining to scale. Since this is one of the main driving mechanisms of our model we need the parameters θ_M and θ_H to be smaller than 1. We choose a moderate value of 0.9 for the **M** sector and a multiple 0.9 of this for the **H** sector.

The magnitude of the linkages is determined by the parameter β, which is set to 0.5. This can be compared to the share of value of intermediate inputs in US manufacturing which is approximately 0.67 (Bureau of Economic Analysis, 2002). We find it plausible that a developing country should have a somewhat lower degree of intermediate usage. Finally, the population size L is normalized to 1.

5.2 First results

A first step is to identify an appropriate cost parameter ϕ. This is done in the model with two sectors, **A** and **M**. Given the parameter specification, a lower bound for the fixed cost parameter ϕ is about 0.13, at which full industrialization is reached. When the fixed cost parameter is set equal to 0.4, aggregate income is 1.041 which is 4.1 percent above the baseline case with no industrialization. The industrialized sector comprises 29 percent of all goods. The fixed cost incurred by firms due to poor infrastructure is approximately 2 percent of aggregate income. We argue that this is a conservative estimate.

We now turn to the model with three sectors. The parameter c is added and set to 0.2. With this parameterization, aggregate income is 1.053 and 29.3 percent of all goods are produced with an industrial technology (**M** or **H**), and 9.9 percent with the **H** technology. Total fixed costs, accruing both to ϕ and c, are now 0.4. This cost falls almost equally on cost due to infrastructure (ϕ) and cost due to higher requirement of human capital (c). It is our presumption that this is as close to a neutral parameterization as we can come.

It is interesting to see how sensitive our parameterization of costs is to changes in the parameters, θ and β. Table 1 presents results for different values of β. For a given cost structure and technology, increasing the density of linkages affects the size of the **H** sector more than the **M** sector. Moreover, total income increases significantly without much change in the number of goods produced by industrial technologies (**M** or **H**). Demand for intermediates increases due to more dense linkages, this benefits firms upstream and makes it feasible to produce more goods with the **H** technology. However, the **M** firms furthest downstream only benefit from increase in aggregate income due to higher profits of other firms.

In table 2 the size of efficiency parameters θ_M is varied (keeping $\theta_H = 0.9\theta_M$). It is evident that the efficiency parameter is the main determinant of growth in the model. When the efficiency of both **M** and **H** technology improves, this increases the relative size of the **H** sector. Table 3 shows the effect of varying the difference between and θ_M and θ_H. As the **H** technology becomes relatively more efficient, it is possible for more firms to bear the fixed costs c.

	2 sectors			3 sectors		
β	0.25	0.5	0.75	0.25	0.5	0.75
$Y(n)$	1.024	1.041	1.089	1.025	1.053	1.132
n_M	0.284	0.289	0.302	0.283	0.292	0.313
n_H	–	–	–	0.026	0.099	0.174

Table 1: Sensitivity to variation in density of linkages

	2 sectors			3 sectors		
θ_M	0.80	0.9	0.95	0.80	0.9	0.95
$Y(n)$	1.240	1.041	1.010	1.298	1.053	1.011
n_M	0.775	0.289	0.133	0.814	0.292	0.094
n_H	–	–	–	0.532	0.099	0.029

Table 2: Sensitivity to variation in efficiency parameter

	3 sectors		
$\frac{\theta_H}{\theta_M}$	0.875	0.9	0.95
$Y(n)$	1.061	1.053	1.026
n_M	0.295	0.292	0.151
n_H	0.187	0.099	0.009

Table 3: Sensitivity to relative efficiency

5.3 Policy Experiments

Table 4 shows the effect of introducing a government of a size 0.02. In other words, the government raises taxes equal to about 2 percent of total income and uses these revenues to either subsidize infrastructure or supply of high-skilled labor. This is a modest size of a government, but bear in mind that its only role is to subsidize either infrastructure or high skilled labor supply. The government in the model should not be equated with a complete public sector. Moreover, the size of government is related to the fact that costs are also relatively small.

Variables	No Policy	Policy 1	Policy 2
$Y(n)$	1.053	1.039	1.072
n_M	0.292	0.289	0.498
n_H	0.099	0.283	0.176

Table 4: Policy Experiments

The difference between policy 1 and policy 2 in terms of effect on aggregate income is striking. Whereas policy 2 increases aggregate output by 1.8 percent, policy 1 actually decreases total income by 1.3 percent. Effects on positions of sector **M** and **H** are as expected, policy 1 promotes the **H** sector, but has a negative effect on the **M** sector. Policy 2 has positive effect on the size of both the **M** and **H** sector.

Next, we let government size vary from 0.001 (approximately 0.1 percent of the total income) to 0.02. Figure 4 plots the resulting paths for the **H** and the **M** sector, and figure 5 plots the development of total income. Policy 1 are associated with solid lines, and policy 2 with dashed lines. The two upper lines in figure 4 describes the **M** sector, and the lines below the **H** sector. Reducing the cost of skilled labor under policy 1 obviously boosts the development of an **H** sector, but as can be seen the effect on the **M** sector, as well as on total industrialization, is negative. Moreover, policy 1 reduces aggregate output (figure 5).

Directing government funds towards improvement of infrastructure, under policy 2, leads to an increase in both the **M** and **H** sector. The **M** sector increases faster than the **H** sector. This is due to the fact that the marginal **M** firm benefits more from the subsidy than the marginal **H** firm. The subsidy gives little incentive for a marginal firm to change from **M** to **H** technology, since the fixed cost $m\phi$ remains almost the same. Nevertheless, some firms do change since the fixed cost is produced more efficiently with the **H** technology. The effect on total income is positive. However, as can be seen in figure 5, total income increases at a decreasing rate.

Next, we explore two pertinent features of the two policies. First, why is aggregate income decreasing under policy 1? The second issue relates to the concavity of aggregate income in government size which suggests that there might be an optimal size of government involvement.

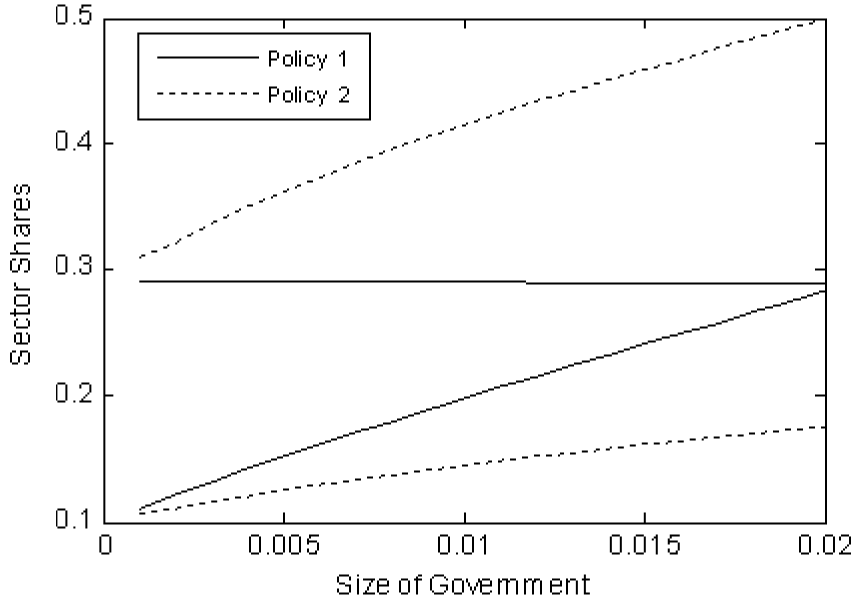

Figure 4: Location of M and H Sectors.

The detrimental effects that policy 1 has on total income at first seems strange. Under this policy, government revenues are used to subsidize **H** firms. The increased profits are distributed to consumers which should counteract the negative effect of the tax on consumer demand. However, the subsidy introduces several other distortions which lower aggregate income. We take policy 1 with a government size equal to 0.02 as an example. Consider first former **M** firms which changes to **H** technology. Due to the use of more efficient technology, revenues in these firms increase by 80 percent. However, cost increases by almost 210 percent since firms now also incur the cost c. The subsidy compensates for part of this increased cost, and allows firms to increase their profits by a total of 22 percent. However, from aggregate perspective, each unit of subsidy directed towards these firms generates only 0.78 units of profits. The same adverse effect is found in the firms which used **H** technology before the subsidy (and continues to do so), here each unit of subsidy generates an 0.68 increase in profits. Demand spillover between these firms falls as the government decreases the cost of using **H**. The old **H** sector is also affected negatively by the more efficient production downstream, this decreases demand for upstream goods as intermediates, and reduces profits

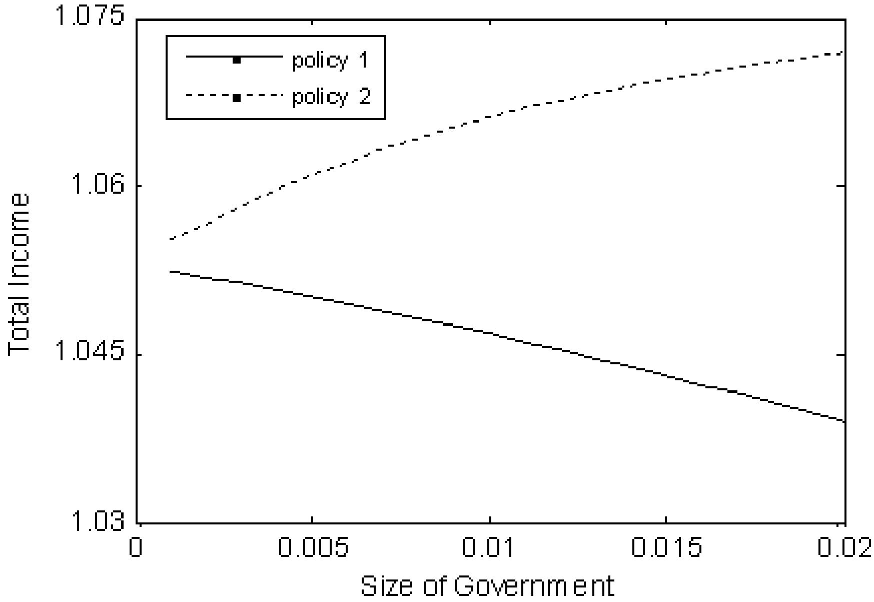

Figure 5: Total Income

further. Aggregate output is also reduced when overall industrialization (**H** and **M**) is pushed back, this effect is however small. The effects are shown in table 5, where the total negative effect should be compared to the reduction in aggregate output in table 4.

Firms	Effect on aggregate output
Exiting **M**	< -0.00001
From **M** to **H**	$+0.0027$
Old **H**, Subsidy	$+0.0048$
Old **H**, Downstream demand	-0.0013
Tax	-0.0200
Total effect	-0.0138

Table 5: Effects of Policy 1

There are two main mechanisms behind these results. First, part of the subsidy goes to firms with few backwards linkages, which are not able to generate much demand in the rest of the economy. Second, part of the subsidy promotes technology upgrading from **M** to **H**. This actually has adverse consequences for firms upstream, since the demand for their products decrease. Furthermore, profits in the firms that change to **H** do not rise sufficiently to compensate for the new fixed cost c that they now incur.

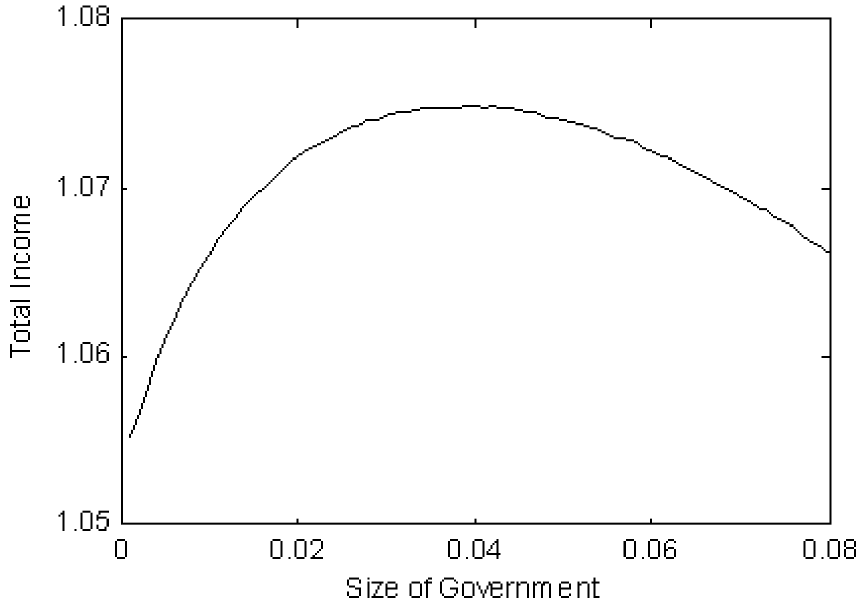

Figure 6: Total Income, Policy 2

In a setting with only the **A** and the **M** sector, the effect of policy 2 is strictly increasing in government size. However, things are different in a model with three sectors. Figure 6 plots the effect on total income of varying the government size from 0.001 to 0.08. This is obviously a concave function which reaches a maximum at a government size of about 0.04. Table 6 summarizes the effects of two government sizes, one close to and one above the optimal level.

The first column shows the index of the firm furthest downstream in each sector, and the second the change in profits in each sector, using no government as benchmark. The ratio presented in the third column gives a measure of how much profit is generated by each unit of subsidy spent. First of all, it is evident that profits in all sectors are increasing compared to the benchmark. Second, it is the firms furthest upstream that benefit the most. The is an artifact of the increase in demand for intermediate input as more firms downstream industrialize. From an aggregate perspective, subsidies are beneficial except in the sector which consists of new **M** firms. It is here that costs related to infrastructure is the highest, and it is consequently into

Firms	Gov=0.036 m	$\Delta\Pi$	$\frac{\Delta\Pi}{Subsidy}$	Gov=0.076 m	$\Delta\Pi$	$\frac{\Delta\Pi}{Subsidy}$
New **M**	0.599	0.014	0.51	0.783	0.029	0.44
Old **M**	0.292	0.008	1.87	0.292	0.002	1.84
From **M** to **H**	0.213	0.013	3.66	0.274	0.027	3.36
Old **H**	0.099	0.023	23.80	0.099	0.033	26.90
Tax		-0.036			-0.076	
Total Effect		0.022			0.016	

Table 6: Effects of Policy 2

these firms that the lion's share of the subsidies will be directed (76 and 86 percent respectively). These firms can only cover part of the cost due to infrastructure through own profits. As more and more **M** firms enter, a larger fraction of subsidies must be directed towards covering fixed costs. The increase in demand and profit upstream is eventually not sufficient to compensate for this cost. Moreover, reducing the fixed cost (while keeping the positions constant) actually decreases demand linkage effects. In addition to this, firms that shift from **M** to **H** will increase their profit, but at the same time generate less demand upstream. The mechanisms here are similar to policy 1.

6 Discussion

The model elaborated in previous chapters captures several of the mechanisms discussed in relation to India. The policy experiments can be thought of as directing government efforts either to facilitate overall industrial activities or to promoting the establishment of high-technology firms. This is another way of capturing the effect of increasing the quality of infrastructure (which is assumed to affect all industrial activities) or to increase the pool of skilled labor (which is assumed to be used in the high-technology sectors). The mechanism that drives our result is the linkage effect between firms. Due to the lower degree of backward linkages from the high-technology sector, a success here does not have the same positive effect as an equivalent expansion of the manufacturing sector. The results show that this mechanism generates substantial effects on aggregate income. Policy 1 can be said to resemble India's industrial policy the most, and the results from our model is consistent with recent experiences in India. A very profitable high technology service sector is thriving whereas basic manufacturing is lagging behind.

The most important issue integral to our model pertains to the interpretation of different sectors. The names we have attributed are somewhat misleading. To recapitulate we have first the **A** sector, which could be thought of as a composite of agriculture and basic services. Second, the **H** sector is a high-technology sector with many forward but fewer backward linkages, in contrast to the manufacturing **M** sector where backward linkages dominate.

There is no introduction of new goods in the model. In a static setting this should pose no problem, but when we perform the policy experiments we implicitly read in some quasi-dynamics. Specifically, we say that a firm transforms from **M** to being a **H** firm, or from being a **A** firm to becoming a **M** firm. How can this be interpreted? Compare the pre-industrial economy to one where the **A** sector make up one half and the other half is the **M** sector. From such a comparison we cannot say that the latter economy differs in the sense that new goods, e.g. automobiles, are available.

A more appropriate interpretation of the sectors is as different functions. The function of for instance transportation was available also in the pre-industrial stage albeit at a much less degree of efficiency than what was later possible with the introduction of automobiles. A similar argument can be made with regard to various sorts of food storage and preparation which as a consequence of industrialization becomes much more efficient. The same interpretation is possible when a firm transforms from **M** to **H**, thereby performing a specific function but now with, for instance, the aid of modern computers. We can also think of outsourcing and the process wherein firms specialize on core competencies as a prototypical case where a function is performed more efficiently. However, in our model it is not an increasing degree of specialization *per se* that causes increasing output, it is the opportunity to tailor a more efficient mode of production to specific functions.

Given the available empirical data, there are obvious problems with this interpretation. In principle this is however a way of identifying the sectors in our model.

7 Conclusions

The majority of the developed economies in the world have displayed a very distinct pattern of industrialization with regards to sectoral shares of aggregate production. Recent trends suggest that India is not following this typical pattern of industrialization. Evidence suggest that while certain high-technology industries are flourishing, growth in basic manufacturing is lagging behind. The contribution of this paper is first to describe these trends and to capture them in a theoretical framework where they are tied together.

Secondly, we extend a recent model in the big-push tradition by allowing for a partial industrialization equilibrium and choice of technology.

Under the assumption that a high-technology service sector buys intermediary inputs from its own sector only, it is shown that the design of industrial policy can have a substantial effect on aggregate income. When mainly directed towards the high-technology sector policy can actually cause a drop in aggregate income. A better way is to promote general industrialization by reducing the fixed costs of industrial production. However, as we have discussed the scope for such a policy is also limited.

The model and results presented captures the static effects of one plausible mechanism. With respect to the specific case of India, there are other equally important circumstances that can explain the lagging manufacturing sector. Exports and remaining institutional barriers are two of the most obvious alternative explanations. However, based on the findings in this study we maintain that it is important to acknowledge the risk of promoting a sector which is isolated, with respect to backward linkages, from the rest of the economy.

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