Economic Complexity as a Determinant of the Industrialization of Countries: the Case of India

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Abstract

We analyze how the complexity of economic systems has played a decisive role at the onset of the industrialization process of countries over the past 50 years (1963-2012). Our analysis of the input growth dynamics along the industrialization patterns, based on the "fitness" of a country, i.e. a recently introduced measure of economic complexity, reveals that more differentiated and complex economies face a lower barrier in terms of GDP per capita when starting the transition towards industrialization. Moreover, the separation of growth patterns between high and low fitness countries clearly shows a dramatic drop in growth due to inputs in high fitness countries when the industrialization has been achieved. In this way current industrialization theories are reconciled with empirical findings. We focus on the industrialization process in India and show that the economic complexity of the country increased between 1963 and 1987, when an impressive increase in GDP per capita marked the beginning of the transition towards industrialization. This process is still ongoing although it seems to have partly lost momentum over the past 4-5 years, as predicted by a decrease in the fitness value of the country.

1 Introduction

The industrialization of a country is a formidable process, deeply changing the population and the institutions of the country while new and old resources are tapped to achieve growth. During this transition the growth rate of the economy is much higher than the global average and much higher than the past and future growth rates of that country.

It is however a transition and, as such, is limited in time. When the industrialization process has touched all the sectors, when the population is educated and near full employment, when all the scale economies have been fulfilled, the process loses its revolutionary power and the new society now sits among the developed countries.

Two questions have haunted economists since the beginning of the discipline, since Adam Smith and Max Weber. The first question concerns the drivers of this sudden sprout of growth: how can an entire society change dramatically in fifty years after being still for thousands of years? Moreover, why is this process suddenly interrupted after catching-up with the other developed countries? There are many competing answers to this part of the puzzle, the most basic being the poverty trap due to multiple equilibria (Solow, 1956): the phenomenon is sudden because there is a barrier – a given level of wealth needs to be reached to start a quick transition to a different equilibrium. There are several alternative explanations, the most notable being the relation between increasing returns and demand, as in Rosenstein-Rodan (1943) and – more formally – in Murphy et al. (1988), in which the barrier to overcome is a minimum internal demand which inhibits scaling returns in manufacturing.

The second question is about the heterogeneity of the process among countries. England experienced its Industrial Revolution in the second half of the XVIII century, followed by other Western countries. In the XIX century the United States became industrialized too, other countries followed in the XX century, while others did not. What prevented countries lagging behind from moving toward prosperity? There are many alternative explanations, ranging from cultural (McCloskey, 2010, Weber et al., 2002), to geographic (Diamond and Ordunio, 1997) and even biological (Ashraf and Galor, 2011). Another explanation is political (Acemoglu et al., 2005): to achieve growth the population has to be empowered through inclusive political institutions, leading to more inclusive economic institutions and widespread prosperity.

In this paper we address both of the questions above by exploring the nature of the barrier to industrialization and its correlation to the complexity of the economy at the onset of the industrialization process. Indeed, along the industrialization path the industrial capabilities of the country, the corresponding products and consumer preferences are completely reorganized, leading to the population's freedom to pursue their own interests in unexpected (new) sectors and entrepreneurial activities. This fact dramatically increases the diversification and the complexity of the underlying economy.

We quantitatively measure the complexity of the economy through a new dimension, the *fitness* of the country, that has recently been introduced in the study of social and economic systems (Cristelli et al., 2013, Tacchella et al., 2012). These share with traditional complex systems the emergence of an unexpected collective behavior coming from the non trivial interactions between their components (Anderson, 1972). The industrialization of a country is a dynamic process in which a complex network reinforcing production capabilities and product demand emerges at the country scale. The prosperity and the potential of a country can be characterized (Cristelli et al., 2013, Tacchella et al., 2012) by considering this new dimension which takes into account the diversification and the complexity of the production system.

In this paper we investigate the role played by this new measure in describing the countries' industrialization process. In order to do so we look at the empirical growth patterns of countries having different levels of fitness. As will emerge, fitness, which is a quantity tuned on the diversification and complexity of the country's export products, carries an important information with regard to the onset of the industrialization process. In particular we will see how a higher country fitness is associated with a lower barrier to industrialization. This empirical finding will motivate an attempt to build a full-fledged model of industrialization taking fitness endogenously into account as a proxy for the growth potential of countries. However, this will only be outlined in the conclusions as its mathematical formulation goes beyond the purpose of this paper.

The case of India is interesting as an instance of recent and still ongoing industrialization. It is particularly relevant to our narrative since the diversification and complexity of India's export basket at the onset of the industrialization process changed abruptly from that of an agriculture based society to that of an exporter of complex products to the global market. But the Indian case is interesting both for its successes and its misfortunes. The heterogeneous history of India's growth, with a long period of low growth and peaks of high growth, allows for a year by year link of its growth history to the nature of its export basket.

We will use the early industrialization of India as an example to illustrate our hypothesis, but we also believe that our findings can account for the further stage of India's growth, which both academics and policy makers may find useful. Indeed, India's export basket, after shifting toward complex products around the turn of the millennium, has lost competitiveness in the recent past and its economic growth has slowed down accordingly. We will argue in favour of the link between the two events.

In section 2, we will describe the data used in the analysis and we will briefly explain the fitness complexity measure and its characteristics. In section 3 we will decompose the economic growth of countries to better define the research question. In section 4 we will discuss the theories currently used in the economic literature to answer our question and we will show some empirical shortcomings of the basic idea of the poverty trap. In section 5 we will show that introducing the fitness in the basic poverty trap hypothesis helps the models to describe the empirical evidence. Finally, in section 6, we will focus on present day India and what policy makers can learn from our approach.

2 Dataset and variables

As mentioned in the introduction, we expect economies showing different levels of complexity (different fitness values) to behave differently in the industrialization process. The idea that economic indicators can be used to summarize the affluence and growth potential of nations dates back to the seminal work of Kuznets (Kuznets, 1946). He introduced the GDP as a measure of nations' productivity in the Thirties in order to better understand how to tackle the Great Depression. Since then a notable number of economic indicators have been proposed (Stock and Watson, 1989). In recent years particular attention has been dedicated to non-monetary indicators (Costanza et al., 2009, Diener and Suh, 1997). The recent notion of fitness introduced to rank nations' development potential (Tacchella et al., 2012) is a non-monetary indicator based on the properties of the network formed by interstate goods exchanges ranked like the Google page ranking (Page et al., 1999). Modern goods markets constitute a network of products similar to that formed by the nodes of the world wide web: ranking algorithms can be efficiently used to characterize the network properties, and in particular to rank nations according to their manufacturing *capabilities* and product complexity.

The idea is the following: each country has a basket of manufacturing *capabilities* which are representative of its underlying social, cultural and technological structure and economy. This (intangible and not directly measurable) basket of capabilities, proxied by the country fitness F, empowers the country to produce (and export) a basket of products. The country fitness F is then related to its export basket: the information of the country growth potential can be extracted from the properties of the worldwide export network. We point out that a simple measure of diversification of a given country is insufficient, since we cannot assume the products as equal in terms of the capabilities required to produce them.[1] Indeed, what is required is a way to weigh the presence of different sectors in a country's economy. For this purpose we need to deal with both the concept of fitness and its counterpart of product complexity. Since the export network also contains the information of product ubiquitousness we can consider a product to be more complex than another if it is not produced by low fitness countries. The complexity of a product increases with the capabilities required to produce it, and the fitness is a measure of both the complexity and the diversification of the exported products.

More formally: the starting point of this type of analysis is the global structure of the matrix M_{cp} whose entries take the value 1 if the country c exports the product p and 0 otherwise. We point out that in order to assign the values to the matrix elements we consider the Revealed Comparative Advantage (Balassa, 1965) of a particular product in a specific country. In this way any trivial correlation with export volumes is removed. Once countries and products are suitably arranged, this matrix M_{cp} is *triangular*, implying the fact that developed countries tend to have a diversified export basket, while poor or less developed countries export fewer and less complex products. While diversification may lead to an immediate (zero-order) estimate of the fitness of a country commensurate with the number of different products it exports, the evaluation of the products' complexity is more subtle: a product exported by low-fitness countries should be assigned a lower score since it is reasonable to expect that a lower level of capabilities is required to produce it. Clearly a linear page-ranking type of analysis cannot handle this point, while a nonlinear ranking approach will be more appropriate.

To calculate the fitness of countries and the complexity of the exported products *we iterate upon convergence* the following set of non linear coupled equations:

$$\tilde{F}_c^{(n)} = \sum_p M_{cp} Q_p^{(n-1)} \qquad (1) \qquad\qquad F_c^{(n)} = \frac{\tilde{F}_c^{(n)}}{< \tilde{F}_c^{(n)} >_c} \qquad (3)$$

$$\tilde{Q}_p^{(n)} = \frac{1}{\sum_c M_{cp} \frac{1}{F_c^{(n-1)}}} \qquad (2) \qquad\qquad Q_p^{(n)} = \frac{\tilde{Q}_p^{(n)}}{< \tilde{Q}_p^{(n)} >_p} \qquad (4)$$

where the normalization of the intermediate tilded variables is made as a second step and n is the iteration index.

The fixed point of these maps has been studied with extensive numerical simulations and it is found to be stable and not depending on the initial conditions. We refer to Cristelli et al. (2013) for a detailed description of this approach.

Countries' fitness evaluations are based on the import-export flows as registered in the UN-NBER database, reconstructed and edited by Feenstra et al. (2005). This database includes the import volumes of 72 countries and covers more than 2577 product categories for a period ranging from 1963 to 2000. Exports are reconstructed starting from these imports, which cover about 98% of the worldwide trade flow. There are many possible categorizations for products;

[1] Indeed, the relation between diversification and economic development is non trivial, as shown in Cadot et al. (2011). Late phases of economic development are characterized by a specialization in more complex products with a consequent drop in diversification.

we will base our study on the Sitc v2, 4-digits coding. After a data cleaning procedure, aiming to remove obvious errors in the database records, and to obtain a consistent collection of data, the number of countries fluctuates between 135 and 151 over the years, while the number of products remains equal to 538.

On the other hand, more recent data are required for section 6. The database we consider is based on the import-export flows of products among countries collected by the United Nations and processed by BACI (Gaulier and Zignago, 2010) and covers the years from 1995 to 2010. The number of products is stable through the years and equal to 1131, while the number of countries varies slightly between 146 and 148. The same data sanitation procedure used for the previous dataset is also used in this case.

Aside from the fitness measure, we will henceforth mostly use simple national economic statistics from Penn World Table 8.0. The data on physical capital is produced with a perpetual inventory method, as described in Inklaar and Timmer (2013), while the proxy for the human capital is the populations' average number of years in education. The exogenous efficiency has been evaluated as the residual part of the total growth after removing the input growth.

3 Identifying industrialization

First of all a quantitative definition of what we call industrialization is needed. In most of countries that will eventually join the other developed nations, the early stages of economic growth are characterized by a period of fast growth. The growth of the Soviet Union that scared the United States administration and economists (Krugman, 1994), the growth of Japan and Southern Europe in the '50s, the growth of the Asian Tigers in the '70s: every country emerging from of an agriculture based economy has experienced a decade or more of extremely high growth while it is catching up with the other developed countries.

The spike of high growth is characterized by a strong increase in investments, both in physical and human capital. While the population experiences new incentives and opportunities for education and investment, the factors of production rise inflating the economic growth. This is what we define as industrialization: the moment in which there is a sudden spike in the factors of production available in the country.

It is indeed possible to decompose the economic performance of a country (either a firm or any other economic actor) in two parts: on one hand the factors of production (Physical Capital, Labor, Human Capital, etc.) and on the other the efficiency with which they are used, i.e. their productivity. Similarly, even GDP growth can be decomposed into the growth of the factors of production and that of their productivity.

3.1 Growth Decomposition

Following Solow (1956), we write the production function as:

$$Y_{c,t} = Y(A_{c,t}, I^j_{c,t}), \tag{5}$$

where $Y_{c,t}$ is the production of country c at time t, $A_{c,t}$ is an efficiency measure and $I^j_{c,t}$ are the different inputs of production (Physical Capital, Labor, Human Capital, etc.) indicated by different js. The production function Y gives the output of the economy for different levels of inputs and efficiency. The growth of the output, that we will henceforth identify with the increase in GDP, can therefore be the consequence of an improvement in the country's efficiency, for example due to technological innovation, or be due to an increase in inputs.

By considering the minimal case of a Cobb-Douglas production function with only two inputs, physical capital $K_{c,t}$ and labor $L_{c,t}$, we write:

$$Y_{c,t} = A_{c,t} K_{c,t}^{\alpha} L_{c,t}^{1-\alpha}. \tag{6}$$

This simple functional shape is useful to empirically quantify the different kinds of growth. Let us first define the labor input L as the product of the number of employees (E) and their associated average human capital (H). Furthermore, defining P as the total population of the country, the per capita GDP will be given by:

$$\left(\frac{Y_{c,t}}{P_{c,t}}\right)_{c,t} = A_{c,t}\left(\frac{K_{c,t}}{P_{c,t}}\right)^{\alpha}\left(\frac{E_{c,t}}{P_{c,t}}H_{c,t}\right)^{1-\alpha}. \tag{7}$$

Moreover, defining with the lowercase letters the growth rates of the respective uppercase variables and the division by population with the hat we have:

$$\hat{y}_{c,t} = a_{c,t} + \alpha\hat{k}_{c,t} + (1-\alpha)\hat{e}_{c,t} + (1-\alpha)\hat{h}_{c,t} \equiv a_{c,t} + \hat{i}_{c,t}. \tag{8}$$

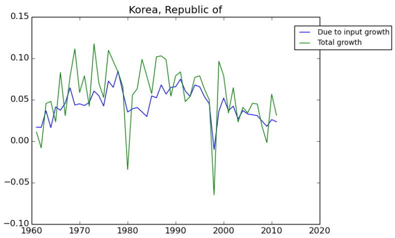
Formula 8 decomposes the growth rate of per capita GDP, $\hat{y}$, in its components: the exogenous growth rate, a, representing the increase in the efficiency; the growth rate of per capita GDP due to per capita physical capital accumulation, $\alpha\hat{k}$; the growth rate of per capita GDP due to an increase of the labor force share in the population, $(1-\alpha)\hat{e}$; the growth rate of per capita GDP due to an increase of the average human capital of workers, $(1-\alpha)\hat{h}$. The latter three form our definition of *per capita input growth*: the physical investment in new machinery ($\hat{k}$), the increase in labor force participation ($\hat{e}$), and the improvement in the education of the labor force ($\hat{h}$): $\hat{i}_{c,t} \equiv \alpha\hat{k}_{c,t} + (1-\alpha)\hat{e}_{c,t} + (1-\alpha)\hat{h}_{c,t}$.

Since the growth rate of inputs is quantifiable, to compute the different parts of the growth in equation 8 we simply need to estimate α. Economic theory is handy in this case. If each factor of production is paid for at its marginal value, the share of national income going to capital is α while the share going to labor is $1-\alpha$. Since these shares are observable numbers, we will use them to estimate α. Finally, the efficiency part, a, can be recovered as a residual after removing the input component from the total growth of per capita GDP.

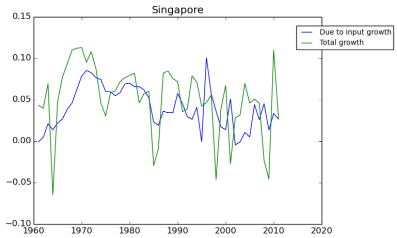
For our purposes we are mostly interested in the per capita GDP growth due to inputs, $\hat{i}$, recovered from equation 8 from national accounting data.

3.2 Input Growth: a transforming society

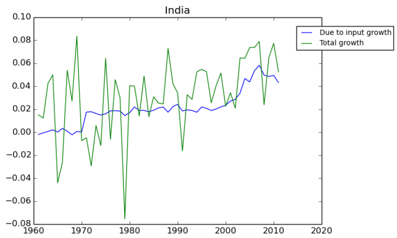
Why are we interested in input growth, and not in total per capita GDP growth? Much of the academic world focused only on efficiency and productivity, assessing that most of the long term growth is due to productivity growth (Hall and Jones, 1999). This is obvious: input growth is intrinsically limited. While a country can double its employment rate from 30% to 60% in the first 20 years of industrialization, it cannot double it again in the following 20 years. While a country can quickly increase literacy rate to 90%, further efforts cannot give



(a)



(b)



(c)

Figure 1: The three plots show the growth of per capita GDP of the three countries between 1960 and 2011. The green line is the total per capita GDP growth ($\hat{y}$) while the blue line is the growth of per capita GDP due only to input growth ($\hat{i}$, from equation 8).

similar payoffs. Input growth suffers from decreasing returns, and it cannot be the focus for long-term growth in developed countries.

However, it is indeed a powerful force at the onset of a country's industrialization. In figure 1 we show the decomposition of growth rates in Input growth for two textbook examples of recent and successful industrialization, South Korea and Singapore, compared with India. As can be seen in all cases during the high growth phase, the excess growth required to catch up with the developed world was obtained through input growth. In the year of maximum growth for Singapore, 1970, out of an impressive 11% growth rate of real per capita GDP, 8% was due to input growth.

Even without decomposing the growth, the transforming effect of industrialization on Singapore is visible by simply looking at the changes in the descriptive statistics in the time span of one generation. In 1966, at the beginning of Singapore's industrialization, 27% of the country population was employed, and 39% of the new entrants in the job market had no formal education. Only 16% of the new entrants in the job market had at least a secondary degree. Furthermore, investments in physical capital were modest, with only 10% of saving rates. The generation entering the job market in 1990 were confronted with a deeply changed country. Female workers had entered massively in the job market, and 51% of the population was now working, almost twice as much as in the previous generation. Among entrants in the job market, only 10% do not have any formal education (one fourth compared with the previous generation) and 54% have at least a secondary degree (a threefold increase). Saving and investing has become common among the population, the savings rate has increased fourfold reaching 39% (Krugman, 1994, Mukhopadhaya, 2002). Not surprisingly, in the same years Singapore's GDP has increased by almost 9 times and the per capita GDP has increased by almost 6 times. Of this exceptional growth, only a modest 25% (around 1% per year, in line with developed countries), can be assigned to a growth in productivity (data from Penn Table 8.1). This is visible in figure 1b: the input growth defines the trend of per capita GDP growth, while the residual productivity increase acts as noise.

The same can be said for the transformation currently occurring in India, even if the process is still ongoing. In just 16 years, from 1994 to 2010, the share of people entering the labor force without any formal education decreased from 60% to 40%. At the same time the new laborers with at least a secondary degree soared to 46% from 27%. The savings rate increased from 24% to 34% (ILO, 2013). In India as well, this change in inputs coincides with a similar increase in GDP (more than 3 times) and per capita GDP (around 150% in 16 years). Only a small part of this increase in GDP can be assigned to an increase in productivity (around 27%, less than 2% per year) (Feenstra et al., 2013). This can be seen in particular in the final surge in figure 1c.

While in developed countries and in countries in an advanced state of development the increase in GDP is mostly due to an increase in productivity, in the first stage of development the growth in inputs is definitely the most impressive driver of growth.

4 A theory at odds with data

While economic theory is mostly an equilibrium theory, industrialization is obviously an out-of-equilibrium dynamics resulting in a shift from one equilibrium to another. Although growth in equilibrium is driven by the growth in productivity, the idea that there can be multiple equilibria and a barrier to overcome to shift from one equilibrium to another was already present in Solow (1956). In the transition the country experiences high GDP growth through input growth. There can be a capital barrier, like in Solow (1956), or a demand barrier, like in Murphy et al. (1988). Still, there is a threshold to overcome in order to access the input driven out-of-equilibrium growth spike. Even in models considering the evolution of a country as a unified process, like Galor and Weil (2000), there are variables that must reach a tipping point in order to move the society into a high growth regime, driven by incentives to invest in production inputs.

Given the explanations proposed, two stylized facts should then be expected to emerge by looking at empirical data:

First, if developing countries catch up with developed countries as a result of the dynamics of inputs shifting their economies to a new equilibrium, we should expect the high input growth of developing countries to sharply decline when industrialization is achieved. We should therefore expect a negative relation between the GDP growth due to inputs and the level of GDP for the countries that have started the transition: the growth should slow down for a developing country while the level of inputs approaches the new equilibrium and the country catches up with the developed ones.

Second, both if the barrier to start the industrialization is demand driven as in Rosenstein-Rodan (1943), or if it is capital driven as in Solow (1956), we should expect that a certain level of GDP/physical capital per capita to be required to trigger the transition. We should therefore find a positive relation between per capita GDP growth due to inputs and the level of per capita GDP for low levels of per capita GDP, where additional per capita GDP means additional internal demand and implies higher per capita physical capital.

To check these expected empirical behaviors we compute the average growth rate due to input versus the country related per capita GDP. We do so by pooling all the countries and years. In particular, we will use a non parametric Gaussian kernel estimation to compute the expected value of the per capita GDP growth rate due to input ($\hat{i}$) and the corresponding confidence interval for different values of per capita GDP. We plot the results in figure 2.

Empirical evidence supports the existence of a barrier to growth, since undoubtedly there is a certain role of prosperity in kick starting investments. However, data do not seem to support the first hypothesis: if any catching up mechanism is visible from the data, it is not as dramatic as expected. The slow down for very high level of per capita GDP, while statistically significant, is hardly economically significant. Surely this is in contrast with the image of calm after the storm that we tried to evoke in the introduction.

Clearly, at this point a crucial ingredient is missing from the analysis: we are unable to pinpoint any possibly different growth potentials among countries.

As is well known, some countries have started an impressive growth process, from an industrial and a social point of view, while others simply rely on the exploitation of natural resources. Given the same level of physical capital or per capita GDP, two different countries could experience very different situations:

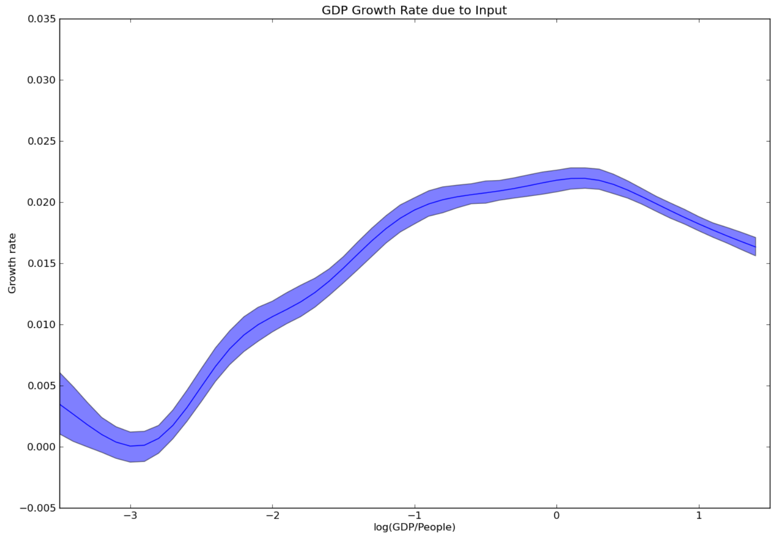


Figure 2: Non parametric kernel estimation of growth rate of per capita GDP due to inputs ($\hat{i}$) versus relative per capita GDP. The shadowing indicates 90% of confidence interval of the expected value, computed with bootstrap. Different countries-years in the range 1963-2000 have been pooled after removing the global trend. While the low performance in increasing their input for countries with low GDP is clearly visible in the figure, the slowing done of input growth expected after catching up is modest.

on the one hand intense investments and shared opportunities for the entire population favoring investments both in physical and human capital, on the other a period of stalemate and complacency, often characterized by exploitive economic institutions and high inequality. To discriminate among these and others situations a quantitative measure is required: a new dimension capable of capturing the heterogeneity of different economies, possibly independent from the others used in the rest of the analysis. We believe that concepts taken from the economic complexity approach may be of help. In particular, we find that the fitness of a country, being both a quantitative measure of the number and of the quality of the capabilities of a nation and a measure of its diversification in advanced and complex products, is a useful indicator of the potential for growth of the country.

Following our line of reasoning that more complex economies may behave differently from less complex ones during the industrialization process, we repeat the above analysis dividing the countries in three quantiles accordingly to their fitness, computed as in equation 1, to see if it helps disentangle the different regimes. In figure 3 we show the results for the high fitness countries compared with the low fitness ones.

When data are split in this way, two different patterns emerge. That which seemed confusing when considering all the countries together is now clearly visible and complies with the predictions in section 3. The high fitness economies,

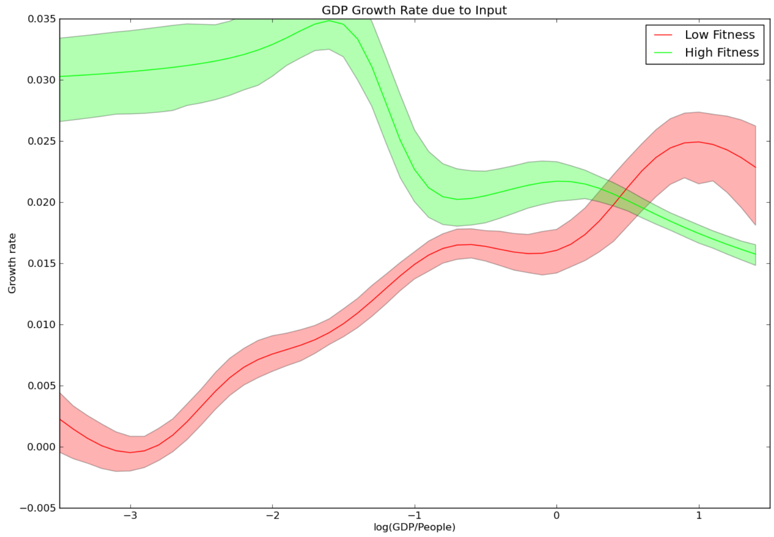


Figure 3: Non parametric kernel estimation of growth rate of per capita GDP due to input ($\hat{i}$) versus per capita GDP for the lowest and the top tertile of the fitness distribution. The shadowings indicate the 90% confidence interval of the expected value, computed with bootstrap. Different countries-years in the range 1963-2000 have been pooled after removing the global trend. Dividing the countries in sets depending on their fitness values highlights very different behaviors and reconciles the theory with the empirical observation.

capable of differentiating their production and exports in advanced products, show a clear downward slope in the growth of per capita GDP due to input with respect to the level of per capita GDP; this finding allows for the interpretation of catching up, and in particular for the transition toward slow growth which is experienced by all the advanced economies. On the contrary, the countries with lower fitness have trouble in starting the transition. They experience a higher barrier and they need a very high level of per capita GDP to achieve the mobilization of resources expected by economic theory. High fitness values appear to lower the barrier which prevents the transition, as we will see it in more detail in the next section.

5 The Cliff toward Economic Growth

In the previous section we observed different behaviors for countries with different fitness levels, hinting at a possible explanation for the industrialization process of a country, which is fostered by high fitness levels. The complexity of the country's economy brings down the barrier to industrialization and allows for investments in inputs. This hypothesis, however, requires further investigation. The different behavior of countries grouped according to their high (green) or low (red) fitness levels (fig. 3), needs to be generalized to a continuous description.

This is the aim of the present section in which we compare the growth rate of per capita GDP due to inputs $\hat{i}$, with both the detrended per capita GDP $\hat{Y}$ and the fitness F. This is achieved by a non parametric estimation of a two dimensional Gaussian kernel obtained by pooling all the countries and years for the time period in question. Contrary to the analysis in figure 3, in which we compared only the behavior of the highest and the lowest fitness countries, we will now explore the complete range of fitness values. This is equivalent to adding a further dimension to the analysis. The results are reported in figure 4. To represent the three dimensions, the dependent variable, $\hat{i}$, is visualized as a color map. To further explain the relation between the two representations, the leftmost part of figure 4 is populated by the same countries lying in the red shaded area in figure 3 (low growth potential countries), while the rightmost part is populated by the countries lying in the green shaded area (high growth potential countries).

This analysis strongly supports our argument: the complexity and diversification of a country's economy, acts as a catalyst in triggering the transition by reducing the necessary per capita GDP. The catching up phenomenon is barely observable in Figure 2 since the plot represents the average of different fitness levels for each level of per capita GDP, thereby mixing up different states of the transition.

Even when starting from very low levels of per capita GDP, high fitness countries are able to start the transition, with increasing investments causing increasing input growth levels. On the contrary, low fitness countries characterized by exports concentrated in few low complexity sectors, require very high levels of per capita GDP to start the transition and attract investments.

It is trivial to adapt this result to a demand-side explanation: there is a complementarity in kindling the industrialization process of a country between fitness, which is a proxy for export competitiveness, and per capita GDP, which is a proxy for internal demand.

However, even a supply-side explanation is consistent with our empirical results, since the opening of new export sectors increases the incentives to invest. One would expect this increase in incentives to be even more visible looking at the residual productivity growth (a). However, if the new accessible sectors allows new - intrinsically different - inputs to be used and accumulated, the scale of production can increase without a corresponding increase in the factor productivity, consistently with an input driven growth.

Low fitness countries with poorly diversified economies do not start the endogenous transition until they have reached an extremely high level of capital.

Figure 4 also displays the trajectory of India in the relative per capita GDP / fitness space, which is a perfect example of our narrative and therefore warrants a discussion. While India's per capita GDP until 1987 remained low, and even lagged behind the world average, its export fitness increased steadily in the period. In 1987, when its per capita GDP was the lowest compared to the world average, and therefore in the most unlikely position for making the transition to an industrial economy according to the classical poverty trap model, its fitness was on the contrary very high. Accordingly, consistent with our hypothesis, its barrier to industrialize was very low: the complexity of the production sectors acted as a major driver for new incentives to investments, to promote education and to encourage people to follow their personal inclinations. As visible in

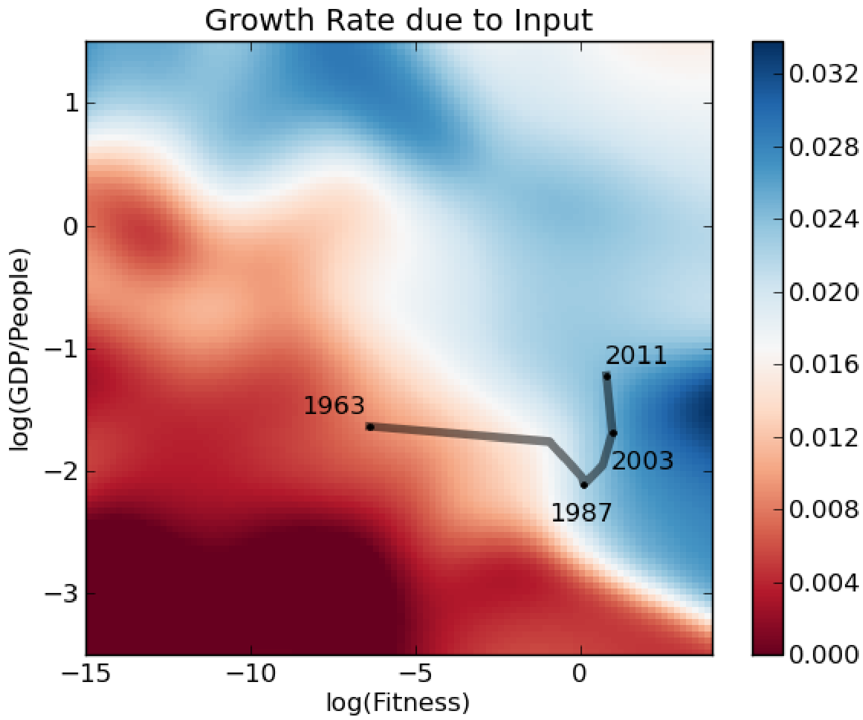


Figure 4: The color map is a smoothed representation of the per capita GDP growth due to inputs ($\hat{\imath}$, from equation 8), for different values of fitness (F, from equation 1) and detrended GDP per capita ($\hat{Y}$). Different countries-years in the range 1963-2000 have been pooled after removing the global GDP per capita trend. Both the role of the fitness of the country in lowering the threshold to enter in the high endogenous GDP growth regime (the blue band in the center) and the slowing down of the process for developed countries (the top-right corner) are evident. The gray line is the trajectory of India's GDP per capita and fitness in the 1963-2011 period.

figure 1c India's input growth soared together with the per capita GDP when the industrialization process started. In 2003 India export fitness was at its highest (we remind the reader that fitness is a relative measure), and per capita GDP was growing steadily. In recent years, however, India's export basket has been slightly losing in complexity and this will be the topic of the next section.

6 India in recent years

India's performance in per capita GDP growth since 2000 has been high and sustained. As mentioned in section 3 this has coincided with high input growth (investments and education). However, in the past couple years the per capita GDP growth of India has been unexciting (approximatly 3.5%). Albeit still steadily above the world average, the performance of other developing countries has been far more impressive.

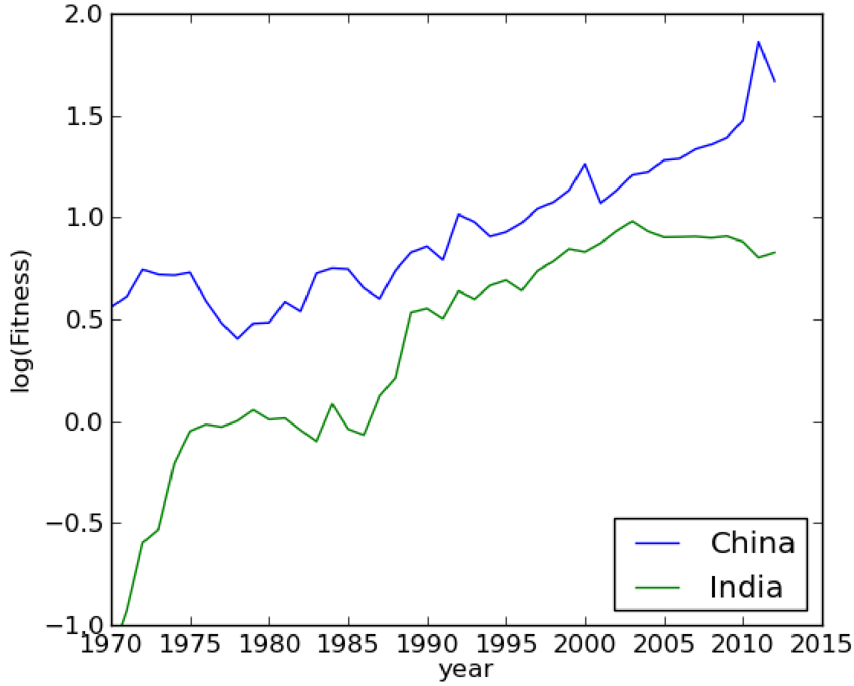


Figure 5: The two lines show the natural logarithm of the fitness measure for India and China in the period between 1970 and 2012. Data for the fitness values in for 2011 and 2012 are not final. The points for 2011 and 2012 are plotted here only for qualitative comparison but their precise value could change in the final estimation of the fitness measure.

Let us now consider the evolution in time of India's fitness and compare it with China (figure 5). After a common upward trend until 2003 the fitness value for India showed a very peculiar drop. While India's fitness was still steadily in the high input growth regime highlighted in figure 4, and indeed in the period between 2003 and 2010 India experienced a sustained level of growth due to inputs as shown in figure 1c, the lack of a further diversification toward more complex products may have paved the way for the subsequent slowdown. This did not occur in China, which continued in the following years to further increase the complexity of its economy, exporting a richer and more diversified basket. This has led to a more sustained growth rate per capita GDP in China.

Looking at equation 1, one can investigate further the causes for the fitness' behavior. Indeed, as is clear from the equation, the fitness can vary both if products are added or dropped from the export basket and if the product complexity changes. These two effects are inherently different. Indeed, the former is due to the country's own industrial policies, while the latter is due to the changes in the global market for the products exported by the country. In formulas, we can decompose a variation $\Delta\tilde{F}$ of fitness[2] as

$$\begin{aligned} \Delta\tilde{F}_c &= \tilde{F}_c(t_1) - \tilde{F}_c(t_0) = \sum_p M_{cp}(t_1)Q_p(t_1) - \sum_p M_{cp}(t_0)Q_p(t_0) = \\ &= \sum_p \Delta M_{cp}\frac{Q_p(t_1)+Q_p(t_0)}{2} + \sum_p \frac{M_{cp}(t_1)+M_{cp}(t_0)}{2}\Delta Q_p. \end{aligned} \tag{9}$$

where in the last passage the two parts have been disentangled. The first element of the sum represents the variation in fitness of country c due to the change in the M matrix, i.e. the changes in the country's export basket. The second element represents the variation of fitness in country c due to the change in the product complexity Q_p, i.e. the changes in the global markets due to new countries entering or exiting from markets in which the country c is an exporter.

We can now look at the reasons for India's peculiar fitness trajectory: the results are reported in table 1. Throughout the time series the products in which India was specializing its export basket increased in complexity, due to competition forcing out the countries with lowest fitness from those markets. However, while in the period from 1996 to 2003 this effect was also coupled with an increase in the diversification that further increased the complexity, in the period from 2003 to 2010 the balance between products added and dropped[3] from the export basket was clearly negative.

	Variation due to changes in the export basket	Variation due to changes in the products' complexity
1996-2003	+28%	+12%
2003-2010	-11%	+4%

Table 1: Decomposition of India's fitness variation in the two components for the time periods before and after 2003. The variations are reported as a percentage of the initial fitness value for the time span in question. Note how the negative variation in the period 2003-2010 is due to products lost from the export basket.

7 Conclusions

In this paper we have shown that simple toy models of countries' growth, in particular models assuming that all countries are homogeneous objects characterized only by one state variable (the per capita GDP or per capita physical capital) are unable to distinguish the different patterns of industrialization. They are therefore unable to predict the starting point of this process, that is the moment in which the countries will emerge from the poverty trap. We have also shown that the introduction of the fitness dimension is able to properly disentangle these different patterns, highlighting countries that are ready to take off and become industrialized as against those that are far from the threshold, notwithstanding a similar sandard of living.

These findings suggest a possible role for the complexity of the economy to drive opportunities and attract internal or external sources of investment. The

[2]note that $\tilde{F}$ is proportional to F except for a normalization factor which varies slowly with time, which is intended to keep the measure consistent among the countries.

[3]we use "added" and "dropped" loosely: as explained in section 2 we are referring to products for which the country started or stopped showing Revealed Comparative Advantage.

increased number of complex production sectors, proxied by the fitness, leads to an open array of possibilities allowing the individual to invest in physical and human capital in order to exploit new and additional opportunities. This effect of fitness on savings and education could be modeled in terms of a dynamical process in which a mutisector economy goes from one equilibrium to another after overcoming a threshold that can be lowered by increasing the complexity and diversification of the economy. We believe that this out of equilibrium dynamics is the one performed by countries emerging from the poverty trap.

Indeed, this analysis does not scrap the concept of poverty trap: if anything, it makes the original point stronger. As can be seen from figure 4, not only is the barrier real but, for countries with low fitness, it is extremely high; to the point that the figure seems to imply the paradox that in order emerge from the poverty trap a low fitness country must *first* become rich. However, it also suggest a different way to overcome both the trap and the paradox, lowering the threshold to industrialization by diversifying exports and making them more complex.

The case of India has been used to illustrate our hypothesis through a concrete example. Indeed, as expected from our argument, India's economy lagged behind, stuck in a poverty trap, for a long time. However, in disagreement with the simple poverty trap theories, what was missing in this case was not simply a certain amount of per capita wealth or income: in fact the industrialization started when India's per capita GDP was exceptionally low compared to the worldwide average. What was missing was a diversified and complex production and export basket that could enable the heterogeneous population to find opportunities and incentives to invest, both in education and in means of production. In the period until the end of the Eighties India changed the structure of its economy and began the industrialization process, making the subsequent growth possible.

We think that our analysis is particularly relevant for policy makers interested in the first steps of development, in particular for the ones interested in countries that are unable to complete their industrialization process even if they enjoy moderately good standards of living thanks to the presence of natural resources. This is not the case of present day India, which has started the development process despite the lack of a high per capita GDP. However, being still so close to the edge of the cliff, Indian policy makers should be wary of any loss in competitiveness particularly with reference to complex products.

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