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Industrial Policies, Patterns of Learning and Development: an Evolutionary Perspective

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2020/08 **March 2020**
ISSN(ONLINE) 2284-0400

Industrial Policies, Patterns of Learning and Development: an Evolutionary Perspective

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Abstract

This work discusses the role of industrial policies within an evolutionary view of innovation and learning as drivers of economic development. Building on the notions of technological paradigms and trajectories, it links the processes of catching-up with the dynamics of capability accumulation within and across firms. In turn such processes are embedded in broader national systems of innovation wherein industrial policies play a pivotal role.

Key words: Technological paradigms – Catching up - Theory of production –Absolute and Comparative Advantages - National systems of innovation - Industrial Policies – Economic Evolution and Development

JEL-classification: O 14-O30-O53-O54 1.

This work significantly draws upon Cimoli and Dosi (1995), Cimoli, Dosi and Stiglitz (2009a), Yu et al (2015) and Dosi and Tranchero (2020). We thank Eva Paus for her insightful comments. Support from the European Union Horizon 2020 Research and Innovation programme under grant agreement No. 822781 - GROWINPRO is gratefully acknowledged.

1.Introduction

Deep relationships of some sorts between technical change and economic development are now generally acknowledged in both economic history and economic theory. Still, their nature is a matter of debate concerning the precise causal links. For example, it is quite intuitive that improvements in the efficiency of techniques of production or in product performances may be a determinant or at least a binding precondition of growth in per capita incomes and consumption. But, intricate debates concern "what ultimately determines what...": e.g. is it resource accumulation that primarily fosters the exploration of novel innovative opportunities, or, conversely, does innovation drive capital accumulation?; do new technological opportunities emerge mainly from an extra-economic domain ("pure science") or are they primarily driven by economic incentives?; should one assume that the institutions supporting technical change are sufficiently adaptive to adjust to whatever underlying economic dynamics emerges from market interactions; or, conversely, are they inertial enough to shape the rates and directions of innovation and diffusion?

These are obviously quite intricate questions. However, there has been over at least the last four decades a flourishing of studies on the sources, mechanisms and patterns of technological innovation, diffusion and imitation. And, the opening of the technological blackbox has often gone together with important insights into innovation-driven market competition. Business historians have finally achieved some cross-fertilization with (some breeds of) economic theorizing. And the institutional understanding of the socio-economic fabrics of contemporary societies starts showing fruitful complementarities with other analyses stemming from the economists' quarters. Quite a few of these contributions have been proposed by scholars who would call themselves evolutionists or institutionalists. Indeed, there is a sense that these diverse streams of research show a few common threads, highlighting the co-evolution of technologies, corporate organizations and institutions (more in Freeman, 2019). These threads - linking evolutionary analyses of the microeconomics of innovation and learning all the way to generalizations on some invariant features of the process of development - are the subject of this contribution. Far from being a comprehensive survey, it is rather a sort of "roadmap". We start by discussing the theoretical implications of what we know about the dynamics of innovative activities at micro and sectoral levels. Technical change is structured by technological paradigms and follows relatively ordered trajectories. In such a view, knowledge accumulation plays a central role (section 2).

A major implication of this view is in terms of theory of production. It is rather straightforward to derive some sort of non-substitution properties, in the short-term, and, also in the long-term: There are firms and countries that are "better", that is more efficient and more innovative, than others irrespectively of relative prices. This implies that technological asymmetries or gaps as permanent features across firms and, even more as, across countries. This is addressed in section 3.

In section 4 we focus on the implications on technical change seen as an evolutionary process in terms of invariances and specificities in patterns of change at sectoral or national level which in turn can be interpreted in terms of some underlying features of the processes of collective learning, market selection and institutional governance.

In Section 5 we focus on the role of industrial policies, written large, and Section 6 concludes.

2. The fundamental properties of technology

Technological paradigms and trajectories

A variety of concepts have been put forward over the last few decades to define the nature of innovative activities: technological regimes, paradigms, trajectories, salients, guideposts, dominant designs and so on. The names are not so important (although some standardization could make the diffusion of ideas easier!). More crucially, these concepts are highly overlapping in that they try to capture a few common features of the procedures and direction of technical change (for discussions and references, see Dosi 1988 and Dosi and Nelson 2010). Let us consider some of them.

The notion of technological paradigm is based on a view of technology grounded on the following three fundamental ideas.

First, it suggests that any satisfactory description of "what is technology" and how it changes must also embody the representation of the specific forms of knowledge on which a particular activity is based. Putting it more emphatically, technology cannot be reduced to the standard view of a set of well-defined blueprints. Rather, it primarily concerns problem-solving activities involving - to varying degrees - also tacit forms of knowledge embodied in individuals and organizational procedures.

Second, paradigms entail specific heuristic and visions on "how to do things" and how to improve them, often shared by the community of practitioners in each particular activity (engineers, firms, technical societies, etc.), i.e. they entail collectively shared cognitive frames (Constant, 1985).

Third, paradigms generally also define basic models of artifacts and systems, which over time are progressively modified and improved. These basic artifacts can also be described in terms of some fundamental technological and economic characteristics. For example, in the case of an airplane, these basic attributes are described not only and obviously in terms of inputs and the production costs, but also on the basis of some salient technological features such as wing-load, take-off weight, speed, distance it can cover, etc. What is interesting is that technical progress seems to display patterns and invariances in terms of these product characteristics. Similar examples of technological invariances can be found e.g. in semiconductors, agricultural equipment, automobiles and a few other micro technological studies.

The concept of technological trajectories is associated to the progressive realization of the innovative opportunities associated with each paradigm, which can in principle be measured in terms of the changes in the fundamental techno-economic characteristics of artifacts and the production process. The core ideas involved in this notion of trajectories are the following.

First, each particular body of knowledge (i.e. each paradigm) shapes and constraints the rates and direction of technological change irrespectively of market inducements.

Second, as a consequence, one should be able to observe regularities and invariances in the pattern of technical change which hold under different market conditions (e.g. under different relative prices) and whose disruption is correlated with radical changes in knowledge-bases (in paradigms).

Third, technical change is partly driven by repeated attempts to cope with technological imbalances which it itself creates. A general property, by now widely acknowledged in the innovation literature, is that learning is local and cumulative. Local means that the exploration and development of new techniques is likely to occur in the neighborhood of the techniques already in use. Cumulative means that current technological development - at least at the level of individual business units - often builds upon past experiences of production and innovation, and it proceeds via sequences of specific problem-solving junctures (Vincenti, 1992). Clearly, this goes very well together with the ideas of paradigmatic knowledge and the ensuing trajectories. A crucial implication, however, is that at any point in time the agents involved in a particular production activity will face little scope for substitution among techniques, if by that we mean the easy availability of blueprints different from those actually in use, which could be put efficiently into operation according to relative input prices.

Paradigms, routines, organizations

A locus classicus in the analysis of the profound intertwining between technological learning and organizational change is certainly Alfred Chandler's reconstruction of the origins of the modern multi-divisional (the M-form) corporation and its ensuring effects on the American competitive leadership over several decades (Chandler 1990, 1992a and 1993). And, as Chandler himself has argued, there are strict links between story and evolutionary theories (Chandler, 1992b). While it is not possible to enter into the richness of the Chandlerian analysis here, let us just recall one of the main messages:

> [...] it was the institutionalizing of the learning involved in product and process development that gave established managerial firms advantages over start-ups in the commercialization of technological innovations. Development remained a simple process involving a wide variety of usually highly product-specific skills, experience and information. It required a close interaction between functional specialists, such as designers, engineers, production managers, marketers and managers [...]. Such individuals had to coordinate their activities, particularly during the scale-up processes and the initial introduction of the new products on the market [...]. Existing firms with established core lines had retained earnings as a source of inexpensive capital and often had specialized organizational and technical competence not available to new entrepreneurial firms (Chandler 1993: p. 37).

As thoroughly argued by Chandler himself, this organizational dynamics can be interpreted as an evolutionary story of competence accumulation and development of specific organizational routines (Chandler, 1992b). Did seemingly superior organizational forms spread evenly throughout the world? Indeed, the Chandlerian enterprise diffused, albeit rather slowing, in other OECD countries (Chandler, 1990; Kogut, 1992). However, the development of organizational forms, strategies and control methods have differed from nation to nation, because of the difference between national environments (Chandler 1992a: p. 283). Moreover, the diffusion of the archetypical M-form corporation has been limited to around half a dozen already developed countries (and even in countries like Italy, it involved very few companies, if any). Similar differences can be found in the processes of international diffusion of American principles of work organization - e.g. Taylorism and Fordism - (for an analysis of the Japanese case, see Coriat, 1990). For the purposes of this work, it is precisely these differences and the diverse learning patterns which they entail that constitute our primary interest. So, for example, a growing literature identifies some of the roots of the specificities of the German, the Japanese or the Italian systems of production into their early corporate histories which carried over their influence up to the contemporary form of organization and learning (see Chandler, 1990; Coriat, 1990; Kogut, 1993; Dursleifer and Kocka, 1993; Dosi, Giannetti and Toninelli, 1993).

Even more so, one observes quite different organizational initial conditions, different organizational histories, and together, different patterns of learning across developing countries. Let us consider them at some detail. During the last three decades, developing countries have shown increased technological dynamics associated with a subsequent development of their industrial structures, thus some significant technological progress did indeed occur in the NIEs and some of them also became exporters of technology.

The evolutionary path of technological learning are related to both the capacity to acquire technologies (capital goods, know how etc.) and the capability to absorb these technologies and adopt them to the local conditions. In these respects, one has now a good deal of microeconomic/micro technological evidence highlighting the mechanisms which stimulate and limit endogenous learning in the NIEs.

Without doing any justice to the richness of these contributions, they seem to suggest the existence of some characteristics in the paths of technological learning at the firm level (see also Cimoli, 1990 and Cimoli and Dosi, 1988). In particular, one might be able to identify some relatively invariant sequences in the learning processes, conditional on the initial organizational characteristics of the firms and the sectors of principal activity.

A first set of regularities regards the varying combinations between acquisition of outside technologies and endogenous learning. As well know, the transfer of technology to developing economies is a common source for the subsequent development of learning capabilities at the firm and sectoral levels. Possibly with too extreme an emphasis, Amsden and Hikino identify the ability to acquire foreign technology as a central characteristic, [...] of late industrialization at the core of which is borrowing technology that has already been developed by firms in more advanced countries. Whereas a driving force behind the First and Second Industrial Revolutions was the innovation of radically new products and processes, no major technological breakthrough has been associated with late-industrializing economies. The imperative to learn from others, and then realize lower costs, higher productivity, and better quality in mid-tech industries by means of incremental improvements, has given otherwise diverse 20th century industrializers a common set of properties (Amsden and Hikino 1993: p. 37).

3. Technological dominance, micro heterogeneity and non-substitution

The notion of paradigms contains elements of both a theory of production and theory of innovation. In short, we shall call it henceforth an evolutionary theory. Loosely speaking, we should consider such a theory at the same level of abstraction as, say, a Cobb-Douglas production function or a production possibility set. That is, all of them are theories of what are deemed to be some stylized but fundamental features of technology and, relatedly, of production processes.

In fact, one finds a few remarkable assumptions underlying conventional production theories. As already mentioned, technologies - at least in a first approximation - are seen as a set of blueprints describing alternative input combinations. Moreover, at any one time there must be many of them, in order to be able to interpret empirical observations as the outcome of a microeconomic process of optimal adjustment to relative prices. Information about these blueprints is generally assumed to be freely available (except those circumstances whereby they are privately appropriated via the patent system). Finally, one assumes to be able to separate the activities leading to the efficient exploitation of existing blueprints from those leading to the development of new ones (exogeneity of technical progress is its extreme version). Of course, this is only a trivialized account of a family of models that can be made much more sophisticated, by e.g. adding details on how blueprints are ordered with respect to each other (more technically, issues like continuity and convexity come under this heading). However, it still seems fair to say that the basic vision of production- also carried over in aggregate growth and development models - focuses on questions of choice among well defined techniques, generally available to all producers, who also know perfectly well what to do with all the recipes when they see them.

Well, to put it very strongly, the theory of production based on paradigms develops on nearly opposite theoretical building blocks. And indeed many of the latter yield empirically testable hypotheses.

Here, we shall argue that a paradigm-based theory of technology may perform the same interpretive tasks, at the same level of generality, and do it better, in the sense that it is more in tune with microeconomic evidence and also directly links with theories of innovation. An evolutionary theory would predict the following.

a) In general, there is at any point in time one or very few best practice techniques which dominate the others irrespectively of relative prices.
b) Different agents are characterized by persistently diverse (better and worse) techniques.
c) Over time the observed aggregate dynamics of technical coefficients in each particular activity is the joint outcome of the process of imitation/diffusion of existing best-practice techniques, of the search for new ones, and of market selection amongst heterogeneous agents.
d) Changes over time of the best practice techniques themselves highlight rather regular paths (i.e. trajectories) both in the space of input coefficients and also in the space of the core technical characteristics of outputs.

Indeed the catching-up in the productivity distributions is a first fundamental mark of successful catching-up processes more generally (more in Malerba and Nelson, 2011; Lee and Malerba, 2017; Landini and Malerba, 2017).

The striking success of China is an excellent case to the point.

Table 1 shows the annual growth rate of labor productivity of incumbent firms, highlighting the dramatic growth of productivity in China’s manufacturing. The overall productivity of incumbents grew at 9.98% during 1998–2007. All sectors display positive productivity growth rates, (except petroleum refining, which had negative growth during the 1998–2002 period).

Further, note the remarkable differences in productivity growth across sectors, as such circumstantial evidence of significant inter-sectoral differences in absorptive capacities (Cohen and Levinthal, 1989) of “frontier,” generally foreign, technologies, and of corresponding differences in the average catching-up rates. Figure 1 offers three snapshots of the non-parametric kernel density distributions of labor productivity, together with the comparison with the corresponding Italian and French ones, as a vivid illustration of the overall technology gaps with two higher income countries.[1] At a first glance the readers might find such a comparison as somewhat far-fetched if one has in mind of a “world production function,” possibly multiplied by some country-specific scalar. After all, Chinese wages have been/are at least an order of magnitude lower than Italian and French ones. As a consequence, one would expect to see the three countries on very different positions on such

[1] We chose Italy and France as we have access to comparable micro data. Our informed guess, based on smaller samples like COMPUSTAT and Orbis firm-level evidences support that the property applied to all “advanced countries”, including the USA and Germany.

production functions. But is it really the case? If it were so, one would also expect, first, major differences between China, on the one hand, and Italy and France, on the other, in capital/ output ratios—the appropriate proxy for "capital intensities" when "production functions" differ. And of course one should expect strong correlations between labor productivities and capital/labor ratios within each country and within each sector. Premise to the following: the proxies for "capital" are very noisy on Italian and French data and just more so on Chinese ones![2]

Remarkably, what the evidence suggests is rather at odds with the conventional wisdom. First, capital/output ratios also at sectoral levels do not differ very much between China and the two considered European countries (cf. Table 2): Indeed they tend to be higher in China!

Second, the within-country, within-sector micro correlations between labor productivities (VA/L) and capital/output ratios (K/VA), for whatever proxy for K is used, is robustly negative in China and is mildly negative in Italy and France (statistics available upon request). Putting it another way, labor and capital productivity are strongly positively correlated. Indeed, under the conventional theories, given relatively uniform relative prices one should not expect distribution of productivities at all. However, they are persistently there even in developed countries (more in Syverson, 2011, and Dosi and Grazzi, 2006) and much more so in developing ones.

Together, third, even within China, labor productivities and capital/labor ratios—as such a proxy of degrees of production mechanization/automation— are basically orthogonal (see Figure 2 for an illustration of a sector out of most).

Overall, the evidence suggests that very little action comes from "moving along isoquants" in response to relative prices. Rather, "best practice" techniques involve a more efficient use of both labor and capital, and relatedly, catching-up fundamentally involves improvements on both dimensions. It is a world of complementarities rather than substitution, wherein technology-gaps and learning efforts are both reflected by *labor* productivity differences, quite independently from relative prices, while TFP proxies might well yield a quite distorted picture of the development process. Indeed, given the ubiquitous complementarities between labor and capital, labor productivities alone turn out to be a robust proxy for the lower bound

[2] Reasons of "capital" are at best biased by construction: witness the old "capital controversy" between the Cambridge, UK and Cambridge, Mass (more in Cohen and Harcourt, 2003 and Shaikh, 2016). And more so are measures simply obtained from balance-sheets. In particular, "capital" measures in the case of China (in firm's balance sheet) are calculated as the value of fixed capital stock at original purchase prices (these book values are the sum of nominal values for different years).

of “true” efficiency distributions within countries, but also across countries, with the added advantage of avoiding any explicit or implicit hypotheses on interfactor substitutability and capital measurements.

Table 1. Annual growth rate of labor productivity over 1998–2007, and subperiods 1998–2002 and 2002–2007 among “continuing” firms (i.e. firms keeping in the same two-digit sector over the relevant period). Source: Yu et al. (2015).

CIC	Sector	1998–2007	1998–2002	2002–2007
13	Food processing of agricultural products	11.25	8.55	13.46
14	Other foodstuff	8.87	5.73	11.22
15	Beverages	10.63	6.20	12.80
16	Tobacco	15.29	11.08	10.65
17	Textile	9.79	10.14	10.54
18	Garments, footwear etc.	7.84	4.84	10.57
19	Leather, fur, feather etc.	7.55	6.52	10.29
20	Processing of timber, manuf. of wood, bamboo etc.	11.87	7.61	14.43
21	Furniture	6.19	4.82	10.40
22	Paper and paper products	10.33	9.48	11.75
23	Printing, reproduction of recording media	8.92	7.54	8.17
24	Articles for culture, education and sports	8.39	7.06	10.03
25	Processing of petroleum, cokeries, nuclear fuel	3.77	-1.61	6.36
26	Raw chemical materials and chemical products	11.40	10.44	11.85
27	Pharmaceuticals	8.94	10.64	7.53
28	Chemical fibers	10.31	12.05	8.85
29	Rubber	8.80	7.01	9.39
30	Plastics	5.83	6.43	6.24
31	Non-metallic mineral products	12.76	9.86	14.71
32	Smelting and processing of ferrous metals	13.86	12.68	14.14
33	Smelting and processing of non-ferrous metals	12.45	13.73	12.64
34	Metal products	5.44	7.84	4.32
35	General purpose machinery	15.40	13.76	15.72
36	Special purpose machinery	16.23	13.09	15.13
37	Transport equipment	12.67	11.64	13.05
39	Electrical machinery and equipment	9.51	8.84	9.32
40	Communication equipments, computers etc.	5.64	8.37	3.30
41	Measuring instruments and machinery	9.62	9.46	9.57
42	Artwork and other	10.01	9.32	12.70

Average	9.98	8.73	10.66

Figure 1: Empirical density (Pr, vertical axis) of labour productivities, whole manufacturing of China, France and Italy, years 1998, 2002 and 2006. Note: The first row - constant 2000 prices and exchange rates (IMF source); the second row - PPP adjusted price (World Bank source). Source: Yu et al. (2015).

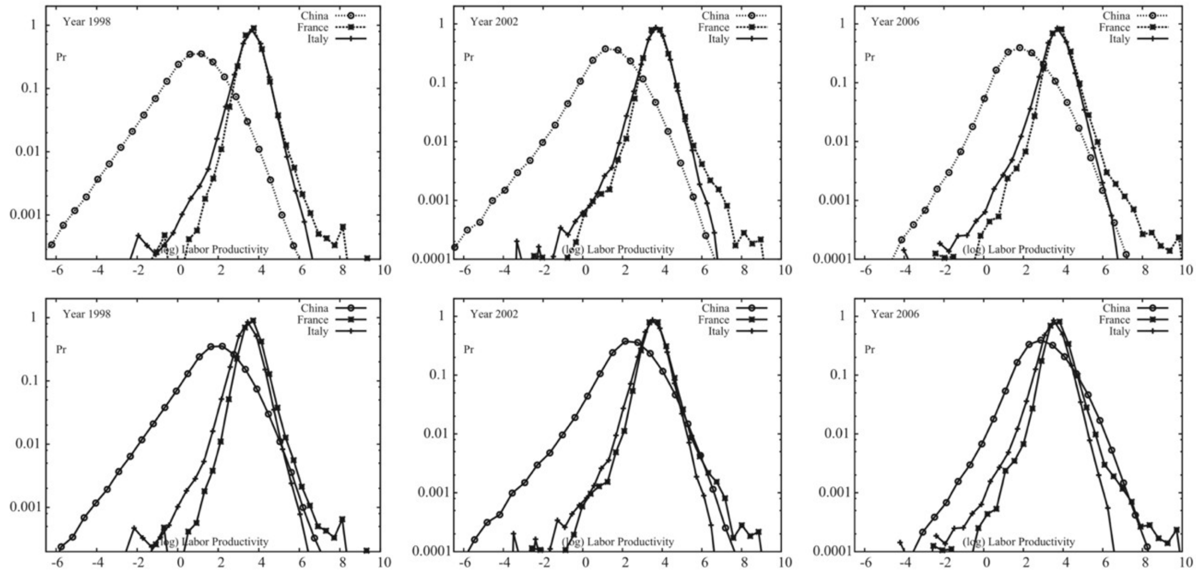
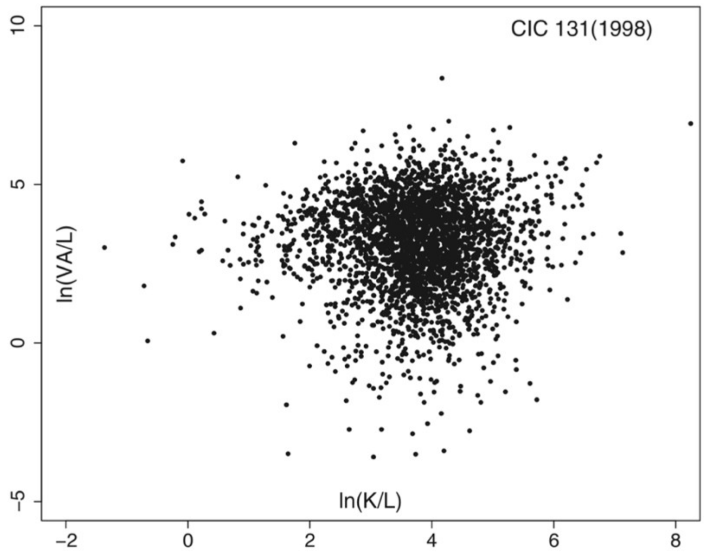


Table 2. The median of capital intensity (capital/output ratios) by sector. *Note*: ❑^{a}∈¿the last column, the France data is year 2004. *Source*: CMM, INSEE (on France), and ISTAT-Micro 3 (on Italy). Source: Yu et al. (2015).

NACE Sector		**China**	**Italy**	**France**	**China**	**Italy**	**France**	**China**	**Italy**	*France*
		1998			**2002**			**2006**		
173	Finishing of textiles	2.772	1.971	1.863	0.732	0.755	0.694	1.228	1.512	1.546
175	Carpets, rugs and other textiles	1.672	1.327	0.789	0.752	0.775	0.688	0.891	0.987	1.055
182	Wearing apparel	1.052	0.785	0.620	0.268	0.276	0.226	0.318	0.318	0.336
193	Footwear	1.062	0.885	0.529	0.29	0.331	0.288	0.488	0.631	0.645
203	Wood products for construction	1.477	0.954	0.629	0.728	0.734	0.763	0.773	0.744	0.736
212	Articles of paper and paperboard	1.475	1.367	1.123	0.824	0.901	0.988	1.025	1.206	1.217
221	Publishing	3.873	5.250	5.716	0.259	0.19	0.117	0.229	0.204	0.192
222	Printing	2.559	2.456	2.084	0.508	0.566	0.562	0.700	0.797	0.792
241	Production of basic chemicals	2.547	1.784	1.049	0.977	1.045	1.153	2.081	2.443	2.811
243	Paints, varnishes, inks mastics	1.312	1.086	0.852	0.584	0.544	0.57	0.946	0.936	1.052

244	Pharma., med. chemicals, botanical prod	1.707	1.514	1.508	0.57	0.623	0.656	0.666	0.83	0.837
246	Other chemical products	1.436	1.167	0.707	0.588	0.628	0.636	0.973	1.004	1.072
251	Rubber products	1.587	1.479	0.974	0.514	0.588	0.495	0.951	1.088	1.03
252	Plastic products	1.614	1.394	1.055	0.714	0.795	0.818	0.969	0.991	1.035
261	Glass and glass products	1.696	1.442	1.079	0.579	0.594	0.742	0.996	1.169	1.198
266	Concrete, plaster and cement	2.084	1.643	1.676	0.93	0.847	0.965	1.365	1.399	1.253
275	Casting of metals	1.113	0.937	0.698	0.669	0.815	0.734	0.886	1.127	1.128
281	Structural metal products	1.290	1.176	0.870	0.433	0.481	0.455	0.547	0.505	0.569
284	Forging, pressing, stamping, of metal	1.981	1.289	0.820	0.574	0.695	0.618	0.77	0.913	0.967
285	Treatment and coating of metals	1.113	0.980	0.923	0.452	0.515	0.467	0.673	0.762	0.803
286	Cutlery, tools and general hardware	1.554	1.068	0.940	0.471	0.584	0.559	0.734	0.861	0.892
287	Other fabricated metal products	1.337	1.018	0.788	0.586	0.626	0.566	0.818	0.921	0.871
291	Machinery for prod. use of mech. power	2.041	1.524	1.012	0.48	0.491	0.408	0.674	0.76	0.714
292	Other general purpose machinery	1.756	1.321	0.905	0.323	0.315	0.272	0.372	0.364	0.361
294	Machine Tools	2.530	1.669	0.961	0.343	0.391	0.289	0.425	0.465	0.466
295	Other special purpose machinery	2.177	1.486	0.977	0.358	0.337	0.332	0.520	0.585	0.614
311	Electric motors, generators and transform	1.570	1.200	0.767	0.369	0.452	0.397	0.510	0.526	0.501
312	Manuf. of electricity distrib, control equip	1.409	1.127	0.781	0.335	0.453	0.352	0.640	0.648	0.553
316	Electrical equipment not e/where class	1.163	0.863	0.671	0.299	0.288	0.275	0.498	0.516	0.497
343	Parts for motor vehicles and their engines	1.781	1.336	1.094	0.526	0.63	0.534	1.088	1.311	1.185
361	Furniture	1.293	1.092	0.798	0.593	0.61	0.564	0.633	0.674	0.722
366	Manufacturing n.e.c.	0.793	0.830	0.808	0.467	0.485	0.405	0.576	0.669	0.781
	Mean	1.713	1.419	1.127	0.534	0.574	0.550	0.780	0.871	0.888
	Median	1.578	1.305	0.914	0.520	0.586	0.561	0.717	0.814	0.820

Figure 2. Scatterplot of log(VA/L) versus log(K/L) for Corn milling sector (CIC 131), year 1998. OLS regression: Coefficient = 0.038 (Standard error 0.029), R^2 = 0.0006, number of observations = 2838. Source: Yu et al. (2015).



In fact the empirical elasticities of substitutions implied by the negative micro relation between labor productivities and capital/output ratios (i.e. positive correlations between labor and capital productivities) are positive in sign: “isoquants” do not look like the standard isoquants but are more similar to rays out of the origin.

Granted all that, let us now focus on the micro picture which the data offer and its dynamics.

Start noting the different upper bounds of the three country distributions, as such an impressionistic proxy of different inter-country lags and leads (together of course with different sectoral compositions of output).

Second, the width of the support of the distribution of China is much larger, revealing much greater technological asymmetries across Chinese firms. The dynamics of catching-up in China’s manufacturing productivity is indeed associated with (i) a rightward movement of the mean of the distributions; (ii) a corresponding rightward movement of the support; and (iii) as we shall analyze in more detail below, a shrinking of the support itself. Labor productivity distribution is asymmetric and left-skewed. The evolving pattern of the left-tail and that of the right-tail are different as well, as the magnitude of left-tail shift toward higher levels of productivity is very significant, compared with a relatively mild movement of right-tail. Such dynamics matches what in the old development literature was called a “reduction of the dualistic structure economy” composed by a shrinking traditional/relatively backward part of manufacturing and an expanding “modern” one, which however is only just beginning to push “frontier technologies” further. An important piece of evidence on intra-sectoral asymmetries in efficiency and their changes over time is the top to bottom ratio of labor productivities. Table 3 displays the ratio of the 9th decile over the 2nd decile for each sector from 1998 to 2007. The ratios decrease in most of the sectors, indicating a reduction of productivity dispersion, plausibly due both to learning by laggard firms and selection (exit) of worse performers. The ratios are generally lower in “traditional” ones (CIC 17–24 including textile, garments, leather, furniture, paper manufacturing, etc.) and higher in relatively technology-intensive sectors (e.g. transport equipment, electrical machinery, and communication equipment). The ratios drop more rapidly in the first part of the period under consideration which is also a period of retreat of SOEs from the so-called “competitive sectors.” At the same time, the ratios in quite a few “heavy industries” such as petroleum refining, and non-ferrous metals sectors grows, hinting at some sort of persistent “dualism” within such industries (note that growing intra-sectoral asymmetries can and often go hand-in-hand with high average growth rates). How much of the dynamics in overall productivity distribution is due to inter-sectoral relocation of production?

Table 3. Ratio of the average labor productivity of the second highest decile over the second lowest one. Source: Yu et al. (2015).

CIC	Sector	1998	2002	2007
13	Food processing of agricultural products	15.62	11.35	10.02
14	Other Foodstuff	19.12	12.20	9.04
15	Beverages	14.89	11.82	9.06
16	Tobacco	17.05	22.95	26.44
17	Textile	8.61	7.01	6.07
18	Garments, footwear etc.	6.51	5.45	5.42
19	Leather, fur, feather etc.	7.80	7.17	6.80
20	Processing of timber, manuf. of wood, bamboo etc.	11.25	6.91	6.51
21	Furniture	9.29	7.15	6.93
22	Paper and paper products	7.44	6.16	6.27
23	Printing, reproduction of recording media	12.47	9.49	6.12
24	Articles for culture, education and sports	6.91	6.10	5.52
25	Processing of petroleum, cokeries, nuclear fuel	8.82	12.26	11.23
26	Raw chemical materials and chemical products	10.30	9.19	8.42
27	Pharmaceuticals	10.65	9.71	8.96
28	Chemical fibers	10.05	6.87	7.98
29	Rubber	6.56	7.49	7.42
30	Plastics	8.65	7.18	7.02
31	Non-metallic mineral products	8.32	7.91	8.23
32	Smelting and pressing of ferrous metals	9.57	8.58	8.40

33	Smelting and pressing of non-ferrous metals	9.70	8.43	12.72
34	Metal products	8.36	7.21	7.12
35	General purpose machinery	8.77	6.68	6.56
36	Special purpose machinery	12.24	9.59	7.25
37	Transport equipment	11.69	8.19	7.09
39	Electrical machinery and equipment	9.39	7.71	8.24
40	Communication equipment, computers etc.	13.52	11.08	8.36
41	Measuring instruments and machinery	12.38	9.00	8.70
42	Artwork and other	8.88	7.38	6.59

Table 4 displays the time series of value-added shares of each two-digit sector in overall manufacturing. It is remarkable that relatively little structural change has occurred over the period under investigation, even if indeed in the 'right direction.' So, for example, the shares of transport equipment, electrical machinery and equipment, and communication equipment, computers etc. are amongst the highest from the start of the period under consideration, and their total share just increases from 20.7% in 1998 to 22.5% in 2007. A synthetic view of the relative importance of the within- vs. between- sectors contributions to productivity growth is presented in Table 5 (for details on the shift-and-share decomposition method of productivity growth, see Appendix).

Of course the precise relative measures of sector-specific learning vs. structural change (what nowadays is often referred to as "re-allocation") depend a lot on the techniques of measurement (e.g. whether the sectoral weights are in terms of employment or value added). So, for example, Paus (2019) find a contribution of the latter of around 19%. However, no matter the measure, the "within component" dominates.

A sign indeed that China achieves quite early a "modern" industrial structure. However, as we shall discuss below this is an exception in the overall picture of catching up experiences. Interestingly, this evidence seems to contradict Kuznets's view of increasing productivity due to structural change, i.e. movements from low-productivity sectors to high-productivity ones also within manufacturing. On the contrary, our evidence suggests that, unlike what happened in the 1980s (cf. Wang and Szirmai, 2008), the movement of the overall manufacturing means is mainly due to sector-specific dynamics. Incidentally, note that "virtuous" structural change is by no means automatic or inevitable. Indeed, the apparent failure to undertake that path appear to be at the heart of the *middle-income trap* with e.g. Latin American countries have experienced: more in Paus (2019).

Of course, the relative stability of sectoral shares at two-digit sectoral level, does not rule out much more turbulence at finer levels of disaggregation within each two-digit sector: indeed, there is very intensive “micro structural change.” However, the evidence marks a difference with other episodes of industrialization and catching-up, in that China appears to be from the period of our observation already quite mature in terms of broad manufacturing structure. For example, when South Korea had the same real per capita income that China had in 1998, which was 1973 (Maddison’s historical statistics www.ggdc.net/maddison/oriindex.htm), it had a share of around 22% of textile and clothing over total manufacturing (World Development Indicators database), compared to a 1998 Chinese share of 12%. In the literature a quite common claim is that export and productivity growth go together (possibly with causality running in both directions). China does indeed display a dramatic rise in the share of export in total manufacturing output and coupled with a dramatic growth in productivity.

However, the Chinese lend little support to the notion of “learning by exporting”.

Figure 3 shows the labor productivity distributions of exporters and non-exporters for the years 1998 and 2007, in some selected sectors (chemical, electrical machinery, and communication equipment) which well illustrate a more general pattern. Note that in 1998 exporters have higher level of productivity and their support of distribution is narrower than that of non-exporters. However, a significant catch-up of non-exporters takes place, so that in 2007, exporters and non-exporters have similar productivity distributions and similar widths of support.[3]

Table 4. Contribution of each two-digit sector to the total value added of manufacturing (percentages). Source: Yu et al. (2015).

CIC	Sector	1998	2002	2007
13	Food processing of agricultural products	4.74	4.50	4.96
14	Other Foodstuff	2.07	1.99	1.99
15	Beverages	3.51	2.69	2.01
16	Tobacco	5.70	5.13	3.11
17	Textile	6.39	5.81	5.23

[3] We are currently exploring the conjecture that within the overall pattern of fast learning by Chinese manufacturing, many “not-frontier” firms found it easier to enter the export markets with the access of China to the WTO.

18	Garments, footwear etc.	3.02	2.76	2.41
19	Leather, fur, feather etc.	1.78	1.76	1.58
20	Processing of timber, manuf. of wood, bamboo etc.	0.82	0.86	1.16
21	Furniture	0.50	0.53	0.69
22	Paper and paper products	2.11	2.17	1.86
23	Printing, reproduction of recording media	1.21	1.11	0.74
24	Articles for culture, education and sports	0.92	0.77	0.60
25	Processing of petroleum, cokeries, nuclear fuel	3.56	3.79	3.52
26	Raw chemical materials and chemical products	7.18	6.96	7.78
27	Pharmaceuticals	2.95	3.29	2.45
28	Chemical fibers	1.19	0.91	0.86
29	Rubber	1.33	1.12	1.02
30	Plastics	2.35	2.47	2.28
31	Non-metallic mineral products	6.03	5.20	5.18
32	Smelting and pressing of ferrous metals	6.47	6.92	9.52
33	Smelting and pressing of non-ferrous metals	2.08	2.24	4.58
34	Metal products	2.98	2.86	3.21
35	General purpose machinery	4.75	4.51	5.46
36	Special purpose machinery	3.33	3.09	3.25
37	Transport equipment	7.41	8.54	7.54
39	Electrical machinery and equipment	5.94	6.12	6.47
40	Communication equipment, computers etc.	7.39	9.64	8.44
41	Measuring instruments and machinery	1.25	1.23	1.24
42	Artwork and other	1.05	0.99	0.86
	Total	100	100	100

Figure 3: Empirical density of (log) labor productivity of exporters and non-exporters of transport equipment (CIC 37) and electrical machinery and equipment (CIC 39) sectors in selected years (1998, 2003, and 2007). Source: Yu et al. (2015).

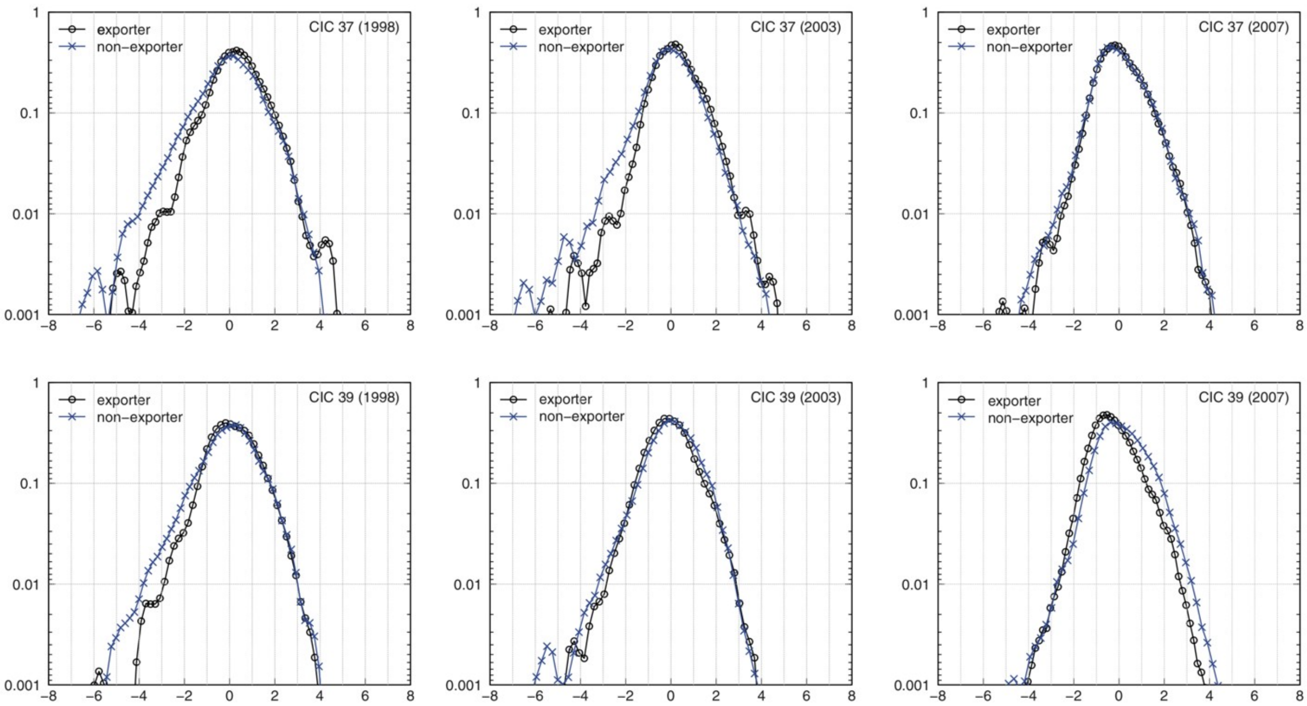

exporter
non−exporter
CIC 37 (1998)
CIC 37 (2003)
CIC 37 (2007)
CIC 39 (1998)
CIC 39 (2003)
CIC 39 (2007)
1
0.1
0.01
0.001
−8 −6 −4 −2 0 2 4 6 8

Table 5. Within sector learning vs. structural change in productivity growth (source: our elaboration on Chinese Manufacturing Micro data)

CIC	Sector	P^0	P^T	Annual Growth (%)	Intra (%)	Shift (%)	Total (%)	P_0	P_T	Annual Growth (%)	Intra (%)	Shift (%)	Total (%)
		1998-2002						2002-2007					
13	Food processing of agricultural products	40.68	74.30	16.25	4.20	0.02	4.22	74.30	165.12	17.32	5.49	0.00	5.49
14	Other foodstuff	35.26	62.07	15.18	1.70	0.01	1.71	62.07	128.80	15.72	2.16	0.00	2.16
15	Beverages	50.30	86.33	14.46	2.57	0.00	2.57	86.33	174.04	15.05	2.32	0.00	2.32
16	Tobacco	311.94	634.26	19.41	6.05	0.00	6.05	634.26	1448.41	17.96	4.79	0.00	4.79
17	Textile	18.91	35.63	17.16	5.78	0.00	5.78	35.63	76.19	16.42	6.41	0.00	6.41
18	Garments, footwear, etc.	23.66	30.34	6.41	1.05	-0.91	0.14	30.34	55.73	12.94	2.40	-0.56	1.85
19	Leather, fur, feather, etc.	25.97	34.54	7.39	0.73	-0.46	0.27	34.54	55.62	10.00	1.22	-0.87	0.36
20	Processing of timber, manuf. of wood, bamboo, etc.	25.94	44.51	14.45	0.68	-0.06	0.63	44.51	94.47	16.24	1.14	-0.42	0.72
21	Furniture	32.34	43.45	7.65	0.22	-0.07	0.15	43.45	67.52	9.22	0.42	-0.67	-0.25
22	Paper and paper products	27.27	55.11	19.23	2.29	0.00	2.29	55.11	132.98	19.26	2.77	0.00	2.77
23	Printing, reproduction of recording media	30.45	59.63	18.29	1.22	0.00	1.22	59.63	111.41	13.32	0.95	0.00	0.95
24	Articles for culture, education and sport activity	24.85	31.23	5.87	0.30	-0.27	0.03	31.23	53.91	11.54	0.65	-0.16	0.49
25	Oil refining, coking, nuclear fuel	67.07	109.05	12.92	2.16	0.00	2.16	109.05	126.24	2.97	0.37	0.00	0.37
26	Raw chemical materials and chemical products	30.88	67.52	21.60	8.75	0.00	8.75	67.52	175.35	21.03	10.18	0.00	10.18
27	Pharmaceuticals	44.94	87.29	18.05	3.21	0.17	3.38	87.29	150.83	11.56	2.21	0.00	2.21
28	Chemical fibers	45.25	76.35	13.97	0.87	0.00	0.87	76.35	158.49	15.73	0.92	0.00	0.92
29	Rubber	27.85	53.94	17.96	1.24	0.00	1.24	53.94	98.40	12.78	0.92	0.00	0.92

30	Plastics	34.86	56.05	12.61	1.73	-0.03	1.70	56.05	85.31	8.76	1.43	-0.41	1.02
31	Non-metallic mineral products	21.61	38.50	15.53	4.96	0.00	4.96	38.50	108.60	23.05	8.28	0.00	8.28
32	Smelting and processing of ferrous metals	34.62	80.27	23.40	8.70	0.00	8.70	80.27	208.33	21.01	10.10	0.00	10.10
33	Smelting and processing of non-ferrous metals	31.86	66.44	20.17	2.47	0.00	2.47	66.44	208.07	25.65	4.70	0.01	4.70
34	Metal products	31.22	52.69	13.98	2.27	-0.04	2.22	52.69	78.37	8.26	1.52	-0.60	0.92
35	General purpose machinery	22.60	51.26	22.72	6.01	0.00	6.01	51.26	145.54	23.21	9.00	-0.10	8.90
36	Special purpose machinery	18.94	47.35	25.74	4.73	0.00	4.73	47.35	144.79	25.05	6.01	0.00	6.01
37	Transport equipment	35.19	85.62	24.89	11.35	0.00	11.35	85.62	202.69	18.81	11.73	0.00	11.73
39	Electrical machinery and equipment	40.51	71.58	15.29	5.13	0.14	5.26	71.58	116.70	10.27	4.30	-0.69	3.61
40	Communication equipment, computers, etc.	68.28	123.44	15.96	7.53	1.98	9.51	123.44	116.55	-1.14	-0.75	-0.05	-0.81
41	Measuring instruments and machinery	31.29	58.45	16.91	1.21	-0.01	1.20	58.45	129.34	17.22	1.70	-0.06	1.63
42	Artwork and other	22.46	34.29	11.15	0.68	-0.25	0.43	34.29	74.24	16.71	1.25	0.00	1.25
	Whole manufacturing	32.73	62.90	17.74	99.89	0.21	100.00	62.90	126.15	14.93	104.58	-4.58	100.00

Note: P^0 is the aggregate productivity in the beginning-year of the period. P^T is the aggregate productivity in the end-year of the period. *Unit* 1000 yuan at 1998 constant price. “Annual Growth” is the compound annual growth rate of aggregate labour productivity. “Intra” is the percentage contribution of within sector productivity growth to overall aggregate productivity growth. “Shift” is the percentage contribution of between sector employment reallocation to overall aggregate productivity growth. “Total” is the overall contribution (i.e., the sum of “Intra” and “Shift” effects) of each 2-digit sector to aggregate productivity growth. The row “Whole manufacturing” shows the contribution of “Intra” and “shift” effects for the aggregated manufacturing sector. Sectors with zero shift effects are the shrinking ones. (For details on the shift-and-share decomposition method of productivity growth, see Appendix.)

Some general interpretative implications

There are many important implications of the foregoing argument. From a theoretical point of view, it implies a radical de-linking income distribution, production theory and development.

In the conventional story every young scholar has to acquire there is an obvious link between technological conditions, input availabilities and remunerations.

It is well known: if production functions are well behaved – homogeneous degree-one, hence no increasing returns, etc. – relative scarcities determine relative input intensities. And if the estimates fall short of full "explaining" output, that goes under the heading of the famous "Solow residual", also re-named as Total Factor Productivity.

The consequences for trade theories are straightforward: The Heckscher-Ohlin-Samuelson theorems follow.

And what about the interpretation of why per-capita incomes differ so much across countries? Over the last few decades a disproportionate amount of efforts has gone into the search of arguments to add to the Kamasutra of variables entering the "production function" (nowadays not only questionable proxies for "culture" and "institutions" but also sinister notions like "genetic endowments").

Here we have taken the opposite route and explored the implications for development of "opening up the black box of technology", to use the felicitous definition of Nate Rosenberg.

Within the black box, one does not find production function and even less so, Cobb-Douglas ones, but rather painstaking efforts aimed at knowledge accumulation, nested in more or less supportive organizations and institutions.

4. Structural change as a fundamental feature of catching–up

The evolution of technological capabilities and production specializations

With the mentioned partial exception of China – which in a sense entered the catching up phase already "mature" in terms of sectoral composition of output - most countries undergo major transformation in the sectors in which they operate and in the products they manufacture (and China is no exception). However, not every country is successful, and, to repeat, many remain grabbed into a "middle-income trap".

In many respects, catching-up entails "climbing up the ladder" of production efficiency – well captured by the dynamics in the productivity distributions discussed in the previous section – but also of product complexities and product demand elasticities.

To recall a discussion of the 90s, the impact on competitiveness and growth of producing potato chips is not identical to that of producing computer chips!

In turn, the climbing up is associated with the *accumulation of technological and organizational capabilities,* often *against the comparative advantages* a country displays. That is, absolute technological levels (and not comparative ones) are a fundamental driver of trade performance, growth and, ultimately, welfare. To clarify the point, Cimoli et al. (2009a) describe the thought experiment of opening up trade between a "Stone Age economy" and an ICT-based one. As Ricardo would argue, the country coming from the Stone Age will be more likely to export "stone-intensive" products for which it has a comparative advantage (and vice versa for the ICT-based economy with, say, computers). However, there could be no bilateral trade at all if the more advanced ICT economy will end up producing almost anything worth trading irrespective of the stone- or ICT-intensities of the products. What really matters for economic growth might ultimately be absolute levels of technological capabilities and how they interact with world demand for products.

An interesting measure in this respect of the "fitness" of a country in terms of the "complexity" of the products in which it is specialized as a predictor of its growth potential is presented in Tacchella et al (2012) and Cristelli et al (2015).[4]

A comprehensive historical overview of successful cases of structural transformations and industrialization is provided by Ha-Joon Chang (2002). The most telling cases of successful latecomers' industrialization are probably the United States, Germany and more recently Japan, South Korea and China.

Indeed, it was the First Secretary of the US Treasury, Alexander Hamilton, who systematically elaborated the infant industry argument in 1791. In a nutshell, Hamilton argued that foreign competition would have prevented domestic industries from becoming internationally competitive, unless the State had intervened to compensate initial losses or to enforce import duties (Hamilton, 1791). American industries ended up being literally the most protected in the world until after WWII (Chang, 2002): needless to say, this goes a long way in explaining the US pattern of structural change. Furthermore, the role of the Federal

[4] A germane attempt characterized however by a few technical drawbacks is in Hidalgo and Hausmann (2009).

government in industrial development has been substantial even in the post-war era, thanks to the large amount of defense-related procurement and mission-oriented research (Mazzucato, 2013; Mowery, 2012). Similarly, in List (1841) we find a very lucid discussion of the shortcomings of simply adhering to comparative advantages: in his view, the true objective of developed countries trying to impose free trade over Europe was simply “kicking away the ladder” that they themselves had climbed (Chang, 2002). The German experience also points to the importance of ad-hoc institutional innovations which facilitated catching-up and were the basis of the successive forging ahead with respect to Britain. Of particular importance was the introduction of the Humboldtian university for the education of graduate engineers, which supplied human capital that proved essential for the diffusion of in-house industrial R&D departments (Dosi et al., 1994). Another pillar of German industrialization was the emulation of imported British machine tools (often thanks to British craftsmen attracted to Prussia, Freeman 1995). More recently, Japan (Freeman, 1987) and the Asian tigers (Nelson and Pack, 1999) were able to reap the benefits from fast growing technological markets. At the roots of the Japanese success there was the explicit decision by Japanese political authorities to neglect the path of “natural” development implied by comparative advantages (Freeman, 2004). In few years, Japan ceased being an importer of foreign technology and developed important indigenous innovation capabilities, even surpassing the United States in terms of R&D efforts. The secret of its success was building up of one of the most successful Innovation Systems (which inspired the formulation of the concept itself, see Freeman 1987), where the long-term planning of the MITI fostered learning and spurred innovation in the export-led industrial complexes.

The classic works mentioned above are detailed case-studies of single countries and their historical experience. More recently, research leveraging natural quasi-experiments and new estimation techniques has allowed the precise causal identification of the effects of sectoral policies. For instance, China’s 11th five-year plan (2006-2010) promoted shipbuilding as a strategic industry for defense-related purposes. Kalouptsidi (2017) finds that the reduction in production costs associated with the policy explains the massive Chinese gains of global market shares in ships: in the absence of the targeted subsidies, China's production would be cut to less than half. Lane (2017) studies the Heavy Chemical and Industry (HCI) policy that South Korea enacted in 1973 as a response to the US troop withdrawal. Again, targeted industries were chosen for their military importance, and the comparison with otherwise similar industries shows that the policy promoted rapid development that lasted long after the measures were removed. Interestingly enough, downstream sectors also benefited from the lower prices induced by the policy, an instance of the policy-induced industrial externalities that Hirschman (1958) labelled “forward linkages”. The HCI entailed both industrial subsidies and targeted trade protection; nonetheless, it must be noted that in certain situations sheer trade protection can be sufficient to change the patterns of trade and allow industrialization. Juhasz (2018) documents that the temporary protection from British imports caused by the Napoleonic Blockade was fundamental in the accumulation of technological capabilities in 19th century France. The mechanized cotton-spinning industry rapidly developed in French departments that received more sheltering, in plain accordance with the predictions of the infant industry argument. Hanlon (2019) complements this evidence by looking at production input advantages, instead of output market protection. Using data from last century’s metal shipbuilding, he shows that even a temporary cost advantage can become the source of long lasting competitive advantage due to dynamic localized learning effects and learning-by-doing. We shall come back to the role of policies below.

Here let us further note that technological catching-up (and of course straightforward innovation) goes hand-in hand with organizational innovation.

5. The crucial role of industrial policies

Some general patterns can be distilled from these historical cases. (For quite germane policy considerations cf. Paus, 2019.)

Emulation and, sometimes, leapfrogging as a general principle inspiring policies

Emulation – we borrow the term from Reinert (2009) – is the purposeful effort of imitation of ‘frontier’ technologies and production activities irrespectively of the incumbent profile of ‘comparative advantages’. It often involves explicit public policies aimed at ‘doing what rich countries are doing’ in terms of production profile of the economy and it always involves microeconomic efforts – on the part of individuals and, more so, firms – to learn how to do things others in frontier countries are already able to do. It is a familiar story over the last three centuries. It dates back at least to the case of England vis-à-vis the Low Countries in the period preceding the Industrial Revolution, and it applies all the way to the contemporary Chinese industrialization. Emulation concerns primarily - as it ought to – products and processes based on new technological paradigms. In one epoch it meant mechanized textile production and the construction of the related machines. Later it was steel production, electricity based products and machinery, and internal combustion engines. Nowadays it has to do first of all with information and telecommunication technologies. In fact, it sometimes happened that catching-up countries not only emulated the leading ones, but 'leapfrogged' in some of the newest most promising technologies. It happened in the 19th century United States and Germany which forged ahead of England in electromechanical engineering, consumer durables, synthetic chemistry. But why should everyone emulate frontier technologies in the first place, rather than being guided by one's own 'comparative advantages'? Or, as the skeptics often put it, isn't it absurd to suggest that everybody should specialize in ICT production? We have answered the question above. Typically, relatively backward economies display an absolute disadvantage in everything, that is they are less efficient in the production of every commodity, and in fact the disadvantage in many commodities is likely to be infinite in the sense that they are not able to produce them at all. Catching-up entails closing the gap in production knowledge and learning how to produce novel goods (which at the beginning are generally novel only for the catching-up country, even if 'old' for the world). This is particularly important with respect to new technological paradigms because such technologies are most often general purpose: they influence directly or indirectly most production activities. For example, it was so in the past (and it continues to be so nowadays) in the case of mechanical engineering and electricity as it is today the case of ICT technologies. Moreover, goods and pieces of equipment based on the new technological paradigms generally entail higher elasticity of demand and richer opportunities for further technological advance (cf. Dosi, Pavitt and Soete, 1990; Castaldi et al., 2009, and Cimoli et al., 2009b). Hence emulation of frontier countries in these activities implies, other things being equal, higher growth possibilities and a greater potential for productivity growth and, eventually, domestic product innovation.

The complementarity between technological learning and the development of production capacity

We have already emphasized above, the difference between technological knowledge and sheer information, bearing important implications in terms of 'stickiness' and difficulty in the transmission of the former – embodied as it generally is into specific people, organizations and local networks. A consequence is also that learning rarely occurs so to speak, 'off line', especially in the initial phases of industrialization. Rather it goes together with the acquisition of production equipment, and with the efforts of learning how to use it and how to adapt it to local conditions (more in Bell and Pavitt, 1993). In turn, this goes hand in hand with the training of workers and engineers and the formation of managers capable of efficiently running complex organizations. These are also the reasons why it is dangerous to see industrialization – even in its early stages - simply as a matter of “diffusion”: the adoption and use of equipment also when acquired “turn key” from abroad, and more so when the technologies are in the form of “blueprints” or licenses require a lot of local painstaking learning efforts. Of course, no policy maker is in the position to fine tune the details of the production activities and together of the patterns of learning which the economy has to exploit. Such details of the actual dynamics depend a good deal on the details of corporate strategies and, why not, on chance. So, just to give an example, there was no way that the Korean policy makers could know, or even less ‘plan’, say, a learning push in semiconductors memories rather than microprocessors. However policy making ought to be acutely aware of the fact that future capabilities build upon, refine and modify incumbent ones: hence the policy goal of building good path-dependencies (the point resonates with a similar advice by Hausmann and Rodrick (2006) when addressing the patterns of product diversification along the development process).

Moreover two fundamental caveats must be kept in mind.

First, a useful distinction can be made between production capacity - covering the knowledge and organizational routines apt to run, repair, incrementally improve existing equipment and products –, and technological capabilities - involving the skills, knowledge and organizational routines needed to manage and generate technical change (Bell and Pavitt, 1993, p. 163). It increasingly happens that the kinds of activities which foster the accumulation of the latter, increasingly involving specialized R&D laboratories, design offices, production engineering departments, etc.

Second, and relatedly, “while various forms of ‘doing’ are central to technological accumulation, learning should not be seen simply as a doing-based process that yields additional knowledge simply as the by-product of activities undertakes with other objectives. It may need to be undertaken as a costly, explicit activity in its own right: various forms of technological training and deliberately managed experience accumulation” (Bell and Pavitt, 1993, p.179) Interestingly, the transition from the production capacity phase to the technological capabilities phase has been managed superbly well by countries like Korea and Taiwan and it is where, on the contrary, most Latin American countries got stuck.

The necessity of nurturing infant industries

Consider again the caricature of a stone-age economy and an ICT economy, and allow them to interact. Two properties are quite straightforward. First, the patterns of economic signals will be quite biased in favor of stone-intensive product in one country, and ICT-intensive in the other (i.e. precisely their current ‘comparative advantages’). Hence if the former wants to enter the ICT age has to purposefully distort market signals as they come from international exchanges (on the assumption that there are some: it could well be that the ICT economy is unwilling to absorb any stone product!). Second, it is quite unlikely that the stone producers even under the ‘right’ kind of signal, will be able to instantly acquire the knowledge to produce competitively ICT products.

Certainly, all individuals take a long time to learn new skills. Turning violinists into football players and vice versa is rather hard, if at all possible. And, even more so, this applies to organizations and organization-building. Even when the transformations are possible, they require time, nurturing and care. If a newly born violinist, ex-football player, is made to compete with professional violinists, he will make a fool of himself. If a catching-up company is suddenly made to compete with the world leaders it will most likely disappear. Often, it is already a daunting task to learn how to make – no matter how inefficiently – a product which might indeed be rather standard in technologically more sophisticated economies: demanding also competitive efficiency is alike asking the violinist to run the 100 meters in around ten seconds after some quick training rounds. Safeguarding the possibility of learning, is indeed the basic pillar of the infant industry logic. On the incentive side, to repeat, market signals left to themselves are often not enough and indeed frequently discourage the accumulation of technological capabilities in so far as they ought to occur in activities currently displaying significant comparative disadvantages and thus also unfavourable current profitabilities. Incidentally note, also, that the existence of financial markets are meagre instruments, if at all, for translating a future and uncertain potential for learning into current investment decisions (more in Stiglitz, 1994). Thus, there are also sound learning-related reasons why the historical evidence shows that, just prior to industrial catching-up, average industrial import tariffs are relatively low; they rise rapidly in the catching-up phase, and they fall after a mature industrialization. Indeed, it is during the catching-up phase that the requirement of distorting (international) market signals is more acute, precisely because there are young and still relatively fragile learning infants. Before there are no infants to speak of. After, there are adults able to swim into the wild international ocean by themselves.

Doing that, however, does not involve only 'signal distortion'. As many of the Latin American experiences have shown, this is far from enough. Partly it has to do with the fact that many forms of protection entail the possibility of learning but not, in the language of Khan and Blankenburg (2009), the 'compulsion' to innovate as distinct from the sheer incentive to just exploit a monopoly rent, no matter how inefficient and lazy is the potential 'learner'. Partly, it has to do with the conditions of capabilities accumulation and the characteristics of the actors involved. After all, even under the best intentions and incentives, our violinist not only will take time to learn but will be able to develop his/her football skills only in a team. In turn, most often, the team will not be the making of sheer self-organization, especially when production entails relatively complex products, as it usually does. At the same time, violin players might not be the best candidate to football playing, irrespectively of the incentive structure. Out of metaphor, industrialization might have rather little to do with the sheer award of property rights and with the establishment of firms as legal entities. In fact, it is quite misleading to think that all over the world there are plenty of sources of technological knowledge just awaiting to be exploited – the lag being due mainly to institutional and incentive-related forces. On the contrary, irrespectively of the opportunities for the entrepreneurial exploitation of technological knowledge which the 'international knowledge frontier' *notionally* offer, the fundamental gap regards precisely the lack of capabilities in exploring and exploiting them. This is a crucial bottleneck for development: such gaps apply to rather simple capabilities which even casual visitors of developing countries notice (whenever walking out of IMF paid hotels…), regarding - at early stages of development – even rather basic activities such as accessing internet or processing a credit card and applies, much more so, to firm-level capabilities such as drilling an oil well (or, at early stages, even keeping an existing well working). As discussed in several contributions to Cimoli, Dosi and Stiglitz (2009a), 'horizontal' policies of education and training, together with the activities of technical support to firms by public institutions can go a long way in the capability-enhancing direction. But even that is not likely to be enough. In fact policies are often bound to get their hands explicitly dirty with respect to the *nature, internal structure, strategies of a few corporate agents themselves*. Fostering the emergence and in a few occasions explicitly building technologically and organizationally competent firms are indeed fundamental infant nurturing tasks. In fact, even the most developed countries present only a fraction of technologically dynamic organizations within a much greater population of firms. (Note that all this applies to both 'high tech' and 'low tech' sectors as conventionally defined). In a sense, industrialization has to do with the properties of changing distributions between 'progressive' and 'backward' firms.

Indeed, all this might not be enough: the State in the past had often to do more than just "pushing and pulling" entrepreneurs into certain strategic sectors, and ended up acting as "entrepreneur of last resort". We believe that this continues to be the case today.

Indeed industrial policies for development and catching up are likely to involve (i) state ownership; (ii) selective credit allocation; (iii) favourable tax treatment to selective industries; (iv) restrictions (or some conditionalilties) on foreign investment; (v) local context requirements; (vi) special IPR regimes; (vii) government procurement; (viii) promotion of large domestic firms (Dahlman 2009 discusses them in the case of China and India , but the lessons are more general).

In a nutshell, this is the full list of the capital sins which the market faithful are supposed to avoid!

6. Industrial Policies in a Sino-centric world: some conclusions

An ensemble of 'infant nurturing' measures, we have suggested, has been a major ingredient of development policies throughout the history of industrialization, and it continues to be so today. Historically, the 'infant learners' had to be shielded or helped in the domestic and international markets essentially in their interactions with the more efficient and more innovative firms from 'frontier' countries. This happens to a large extent also today. However, the unique feature of the current 'Sino-centric' world - as Castro (2009) puts it – is that many catching-up countries are, so to speak, caught between two fires: the developed world is still ahead of them, but at the same time China quickly reduces its absolute disadvantages across the board, in both more traditional productions and in activities based on the newest technological paradigms. And it does so at rates higher than its catching-up in wages (notwithstanding the fast growth of the latter). The outcome is an absolute cost advantage in an expanding set of goods including those which were/are central to industrial production of many low and middle income countries. In that respect the magnitude and the speed of Chinese industrialization risk exerting a sort of crowing out effect vis-à-vis the industrializing potential of many other countries. So, for example, Brazil – a country indeed on the upper tail of the distribution of industrializers in terms of technological capabilities –

turns out to be a very ‘high wage’ country as compared to China, but so are also other less developed Latin America countries, and even African countries are losing cost-based international (and domestic) competitiveness vis-à-vis China. A reason to give up the ‘infant nurturing’/capability accumulation philosophy? In our view it is not: on the contrary, it adds to the reasons urging to practice various combinations of the ‘capital policy sins’ mentioned above. And it ought to push toward a more explicit use of the domestic or regional markets as venues of culture of an emerging national industry even when the latter tends to be squeezed on the international arena between ‘advanced productions’ and Chinese exports.

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Appendix: Shift-and-share decomposition methodology

To measure the contributions of structural change to aggregate productivity growth, it is crucial to distinguish between the contributions of shifts between sectors and the contributions of productivity growth within sectors. Notice that we use an aggregated dataset based on our firm-level dataset for using the decomposition method below.

Recent studies using shift-share technique include Ali Akkemik (2005), Timmer and Szirmai, (2000) and Kumar and Russell (2002). We adopt van Ark and Timmer (2003) shift-share model, in order to be comparable with the results of Wang and Szirmai (2008).

The difference in aggregate labour productivity levels at time 0 and *T* can be written as

$$P^T - P^0 = \sum_{i=1}^{n} \left(P_i^T - P_i^0 \right) S_i + \sum_{i=1}^{n} \left(S_i^T - S_i^0 \right) P_i \quad (1)$$

with P_i^0 and P_i^T the labour productivity of sector *i* at year 0 and T; S_i^0 and S_i^T the employment share of sector *i* at year 0 and T; $S_i$sector’s period average share of total employment, and P_i sector’s period average labour productivity. The growth of aggregate productivity can be decomposed into intra-sectoral productivity growth (the first term on the right-hand side of equation (1), called “intra-effect”) and the effects of changes in the sectoral allocation of labour (the second term, called “shift-effect”). Let C_i denote the contribution of sector *i* to the aggregate labour productivity growth. We have

$$P^T - P^0 = \sum_{i=1}^{n} C_i = \sum_{i=1}^{n} \left(C_i^{intra} + C_i^{shift} \right) \quad (2)$$

van Ark and Timmer (2003) reallocate all shift effects (C^{shift}¿from sectors that experienced shrinking labour shares to sectors that expanded their share in total labour. Suppose *K* is the set of sectors which expand their labour shares; J is the set of sectors with declining labour share. For expanding sectors k and shrinking sectors j,

$$C_k = C_k^{intra} + C_k^{shift} = \left(P_k^T - P_k^0\right) S_k + \left(S_k^T - S_k^0\right)\left(P_k - P_J\right) \quad \forall k \in K \qquad (3)$$

$$C_j = C_j^{intra} = \left(P_j^T - P_j^0\right) S_j \ \forall j \in J \qquad (4)$$

with average labour productivity overall shrinking sectors and averaging over years

$$P_J = \sum_{j \in J} ¿¿¿ \ . \qquad (5)$$

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