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Technical progress and structural change: a long-term view

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Technical progress and structural change: a long-term view

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Abstract

Along the development path, countries experience large transformations in their economic structure as productive resources move towards different economic activities. "Modern economic growth" is also associated with a self-sustained process of technical change which leads to the emergence of new products and sectors characterized by different scopes for productivity gains and demand growth. In this paper we study the interactions between structural change and technological progress from a long-term perspective. We first analyze the secular patterns of structural change across agriculture, manufacturing and services using historical data in the attempt to test some broad conjectures concerning sectoral reallocations at different stages of development (i.e. the so-called Petty-Clark law) and discuss the specific role of manufacturing as an engine of growth. Second, we provide an overview of the literature on sectoral innovation patterns as well as of recent evidence linking structural transformations and sector-specific technological opportunities to aggregate productivity growth. In the final part we present productivity decompositions using a sectoral innovation taxonomy to study the contribution of different groups of activities characterized by heterogeneous innovation patterns. Our results suggest that structural change towards knowledge-intensive activities provides a source of productivity growth in both developing and advanced countries. In turn, this points at the need for a more disaggregated analysis of structural change to capture the diversity in the rate and direction of technical progress across sectors.

Keywords Long-run development, structural change, technical change, productivity growth

JEL classification O1, O14, O3

1 Introduction

It is widely acknowledged that structural change, defined as the transformation of the sectoral composition of the economic system, is one of the salient features of "modern economic growth". Traditionally, in a long term perspective, structural change is understood as a long-term process of reallocation of economic activity across the three main sectors of the economy namely, agriculture, manufacturing and services.[1] Interestingly enough, notwithstanding the widespread appreciation that economic growth has been accompanied by structural change, a large part of modern conceptualizations of the process of economic growth have been formulated in terms of idealized economic systems consisting of one sector (Solow, 1956). This neglect may be probably accounted for by the implicit notion that, for many purposes, structural change is a sort of an epiphenomenon and one can study the fundamental properties of the growth process without taking explicitly in consideration the details of the changing morphology of the economic system. Still, even if this "aggregate" perspective is predominant, it

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[1]The three sectors breakdown in agriculture (primary), manufacturing (secondary) and services (tertiary) was explicitly emphasized by Clark (1940). For a compact overview of Clark's contributions, see Maddison (2004).

is possible to find several contributions that regard structural change and growth as intimately connected and worthy of explicit consideration.[2]

Interpretations of economic growth that highlight a prominent role for structural change point to the existence of fundamental differences across sectors in terms of technological opportunities, and relatedly of their potential for productivity growth. The "sectoral heterogeneity" in technological opportunities provides the fundamental connection between structural change, technical progress and aggregate economic growth, since it implies that the overall pattern of economic growth will be essentially shaped by the shifts in the sectoral composition of output. It is however important to recognize that patterns of structural change are also driven by factors acting on the demand side since income elasticities across products (sectors) are also heterogeneous and change over time. In this perspective, economic growth is also shaped by a reconfiguration of the patterns of demand, which in turn affect the growth and decline of the different sectors. This interplay between supply and demand factors is at the root of the historical process of structural change (Pasinetti, 1983).

A basic characterization of the process of structural change in the long-run is the so-called Petty-Clark law. Colin Clark (1940, p. 176) noted that the "movement of working population from agriculture to manufacture, and from manufacture to commerce and services" was the "most important concomitant of economic progress". Clark dubbed this view as "Petty's law", pointing out that the notion had originally been adumbrated by the 17th century English economist William Petty in his *Political Arithmetick*. In fact, given the significance attributed in Clark's volume to the disaggregation of the economic system in agriculture, manufacturing and services, it is probably most appropriate to refer to the notion as the "Petty-Clark law" (Pyatt, 1984).

The main goal of this chapter is to reassess to what extent this and other broad conjectures concerning the long run interaction between technical change and structural change are corroborated by the data. The chapter proceeds as follows. In the next section we provide a compact summary of the major contributions that have articulated conjectures concerning the nexus between long run trends in technology and structural change. Section 3 contains a reconstruction of historical patterns structural change against the background of the broad contours of technological progress since the industrial revolution. Section 4 considers the evidence on the role of manufacturing as "engine of growth". Section 5 discusses the evidence concerning the difference in sectoral patterns of inventive activities and elaborates the implications for the study of structural change. Section 6 documents recent trends in structural change in five major country groups and present results from productivity decomposition analysis taking into account differences in patterns of inventive activities. Section 7 concludes.

2 Technical progress, structural change and modern economic growth

A suitable starting point to discuss the literature on the connection between structural change and innovation is Simon Kuznets' appraisal of the process of modern economic growth. According to Kuznets, "modern economic growth" represents a distinctive historical "epoch", which is characterized by "the extended application of science to the problems of economic production" (Kuznets, 1966, p. 9).[3] Kuznets highlighted six main fundamental characteristics of the process of modern economic growth, namely:

1. High rates of growth per capita output (and of population)
2. High rates of growth of productivity (of all inputs)
3. High rates of structural transformation including shifts of employment from agriculture to industry and services

[2]Structural change has received considerable attention by heterodox scholars, working mainly in the evolutionary and post-Keynesian traditions, in their growth models (see e.g. Cornwall, 1977; Pasinetti, 1983; Verspagen, 1993; Saviotti and Pyka, 2008; Montobbio, 2002; Ciarli et al., 2010; Lorentz et al., 2016; Ciarli et al., 2017). Dosi et al. (2019) have recently developed a multi-country, multi-industry agent-based model which combines Schumpeterian and Kaldorian insights and displays structural transformations as an emergent property. Over the last years, increasing importance has been attributed to structural change also by Neoclassical models (see e.g. Kongsamut et al., 2001; Rogerson, 2008; Temple, 2005; Ngai and Pissarides, 2007).

[3]It is important to stress that Kuznets adopted a broad conceptualization of science: "By science we mean the study of observable and testable characteristics of the physical world in accordance with the canons of validity accepted by groups of practitioners called scientists. By science-based technology we mean applied knowledge which rests, in the reliability of its predictions and practices, upon the verified general knowledge in the sciences and upon specific observations on materials and so on" (Kuznets, 1966, pp. 9-10). In perspective, Kuznets' definition resonates with Joel Mokyr's notion of useful and reliable knowledge (Mokyr et al., 2002).

4. Changes in the structure of society and its ideology, including modernisation and secularisation
5. Growing expansion of global trade and international economic activities prompted by improvements in transport and communication technologies
6. Growing gaps in economic performance between advanced and backward countries

Interestingly enough, these six characteristics can be grouped in three broad domains: characteristics 1 and 2 concerns aggregate growth, characteristics 3 and 4 concerns structural change, characteristics 5 and 6 revolves around globalization (Kuznets, 1973). When Kuznets wrote, he could rely only on very limited and fragile data. Since then, substantial progress on long run patterns of economic growth has been obtained.[4] Kuznets' idea was that the structural transformation was inherently related to the shifts in the "locus of technological change" across different industrial sectors (Kuznets, 1966, pp. 155-156). In Kuznets'view (Kuznets, 1930), at sectoral level, modern economic growth was actually driven by a sequence of "leading sectors" undergoing a life-cycle with a first phase of rapid growth, followed by a phase of deceleration ("retardation"). This perspective on structural change is clearly in line also with the perspective of Schumpeter and "neo-Schumpeterian" scholars such as Freeman, Louca and Perez (Freeman and Louçã, 2001; Perez, 2003).

From our perspective, the key point stressed by "neo-Schumpeterian" scholars is the emphasis on the critical role of discontinuities in the broad contours of technical change. These discontinuities are related to the successive deployment of a sequence of "technological systems" or "techno-economic paradigms". The notion of technological system refers to constellations of major innovations characterized by strong technological and economic linkages. One can think as a possible example to the interdependencies and complementarities between machine-tool technology, steam engine and iron production during the industrial revolution.

According to Freeman and his associates, the gestation and deployment of each "technological system" exerts a major impact on the rate of economic growth by means of direct backward and forward linkages, technological spillovers, and more general cost reductions of particular products. Furthermore, they argue that the sequence of these technological systems generates a pattern of growth characterized by long (Kondratiev) waves of economic development, with a duration of about 50 years for each wave as originally postulated by Schumpeter (1939). Both the periodization of the economic growth in terms of Kondratiev waves and the connection between economic activity and the technological systems identified by Freeman and his collaborators remain, to this day, controversial (Nuvolari, 2018). In particular, considering that some of the constituting elements of the technological systems identified by Freeman and his associates (such as steam power or electricity) are characterized by particularly extendend cycles of development, in some cases spanning even more than 100 years (Freeman and Louçã, 2001, p. 145), it is not straightforward to interpret the deployment of these large scale technological system in terms of a rigid Kondratiev wave chronology. If this is the case, than at each moment of time, the productive system will be characterized by "layers" of different technological systems that co-exist and interact. In this perspective, a more simple periodization, based on the traditional distinction between "first", "second" and "third" industrial revolutions seem to provide a better characterization of the process of economic growth than the Kondriatev chronology (Von Tunzelmann, 1995, pp. 97-100; Nuvolari, 2018).[5]

Table 1 provides a stylized overview of the characteristics of the three industrial revolutions. The table provides a vivid illustration of the potential connection between technology and structural change. Each industrial revolution both resulted in a re-articulation of existing productive systems (think to the reconfiguration of the factories layout prompted by the adoption of electric power) and in the emergence of new products and industries (coupled with the disappearance of some old products).

The constellation of innovations of each industrial revolution prompts trajectories of improvement that are mutually interacting, possibly reinforcing each other in a "autocatalytic" fashion. This means that innovations in one sector are, simultaneously, dependent from innovations in other domains, but also capable of inducing further advances in related sector. This perspective concerning the emergence of "autocatalytic" connection between technological trajectories at sectoral level is reminiscent of the notion of "development blocks" introduced by

[4]see Broadberry, 2016, for a reassessment of Kuznets'contribution in the light of the most recent data of the Maddison project

[5]For a contribution highlighting the connection between structural change and the three industrial revolutions in the US case, see Lee and Rhode (2018).

	First industrial revolution	Second industrial revolution	Third industrial revolution
Approximate timing	1750-1870	1870-1969	1969-
Technological base	Mechanization	Automation	Automation/information processing
Power systems	Water power; Steam power	Electricity	Electricity (Nuclear, renewables); Lithium battery
Leading sectors/ Carrier branches	Cotton textiles; Iron; Mechanical engineering (machine tools)	Steel; Chemicals; Automobiles; Consumer durables	Electronic components; Computers; Software; Telecoms
Core inputs	Cotton; Coal; Iron	Oil; Steel; Plastics	Silicon
Organization of firms	Factory	Large business firms; Multinationals	Large and small firms; Networks
Infrastructure	Turnpikes; Canals; Railways	Highways; Airports; Telegraphy; Telephone	Telecom; Internet

Table 1: Key-Characteristics of the first, second and third industrial revolutions

Year	Agriculture	Industry	Services
1381	57.2	19.2	23.6
1522	58.1	22.7	19.2
1700	38.9	34	27.2
1759	36.8	33.9	29.3
1801	31.7	36.4	31.9
1851	23.5	45.6	30.9

Source: Broadberry et al. (2015).

Table 2: Share of labour force by sector in England (1381-1700) and Great Britain (1700-1851)

the Swedish economist, Erik Dahmen (Carlsson and Henriksson, 1991) and of "leading sectors" put forward by Rostow (1960, 1990).

3 Structural change and modernization

Kuznets and Colin Clark regarded the shift of employment from agriculture to manufacturing and, subsequently, to services as one of salient features of modern economic growth. Recent research suggests that the shift was more gradual than Kuznets' notion of "high rates of structural transformation" suggests. Furthermore, in countries such as England and the Netherlands the shift began already in the early modern period, actually preceding the industrial revolution. Table 2 shows some recent estimates for England that shows that a significant decline of agriculture had already taken place in the period 1500-1700.

Data for the period before 1800 are available only for a very limited number of countries. For the period after 1800, data on the sectoral composition of employment and output are available and they allow to investigate long run patterns of structural change.

Figure 1 displays the long run evolution of the shares of employment and value added for 18 (mostly advanced) countries. Figure 2 shows the dynamics of sectoral employment shares at different income per capita levels for the "aggregate" across different country groups.[6]. In Figure 3 we plot sectoral shares of output (value added) and

[6] See the Appendix A for details on aggregation and country groups.

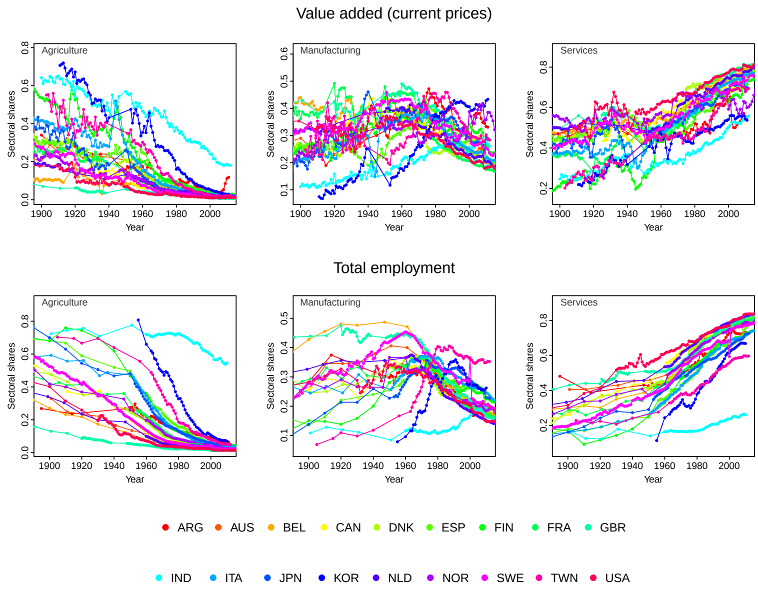

Figure 1: Long-run evolution of sectoral shares of employment and value added

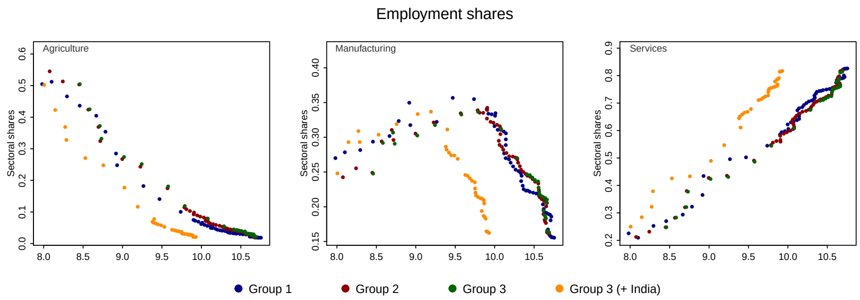

Figure 2: Sectoral employment shares versus income per capita aggregated across different country groups

employment against real GDP per capita.[7] Data points are divided into three periods corresponding to major industrial revolutions. Data for historical sectoral shares have been collected using different sources which are summarized in Table A.1 in the Appendix A. Figure 4 includes in the same plot also the observations for less developed countries which are available only from 1950. Table 3 shows the predicted values of sectoral shares and other outcomes of the modernization process such as education, life-expectancy and urbanization at different levels of GDP per capita. The model used for predictions is the following polynomial regression:

$$DepVar_{i,t} = \beta_0 + \beta_1 \log y_{i,t} + \beta_2(\log y_{i,t})^2 + \beta_3 \log Pop_{i,t} + \beta_4(\log Pop_{i,t})^2 + \sum_{i=1}^{N} D_i + \epsilon_{i,t}, \tag{1}$$

where y stands for real GDP per capita, Pop is population and D represents the country fixed effect. As dependent variables we use respectively the sectoral shares, the average years of schooling (SCHOOL), life expectancy(LIFEXP) and the urbanization rate (URBANIZATION). Details on data sources for modernization variables are documented in Appendix A. The simulated dynamics of the model assuming a representative country with median population is reported for each variable in Figure 5 while model estimates are given in the Appendix B (cf. Table B.1).

The main finding emerging from Figure 3 and Table 3 is that Petty-Clark law of the movement from agriculture to manufacturing and to services is a broadly accurate conjecture. Interestingly enough, there seems a broad correspondence also between patterns of structural change and the periodization of the three industrial revolutions we have outlined in Table 1. Nevertheless, such correspondence turns out to apply exclusively to first industrializers whereas structural transformation for less developed countries appears to be more disconnected

[7]The same exercise is presented in Herrendorf et al. (2014). Here we extend their analysis by considering a broader set of countries and a larger time span.

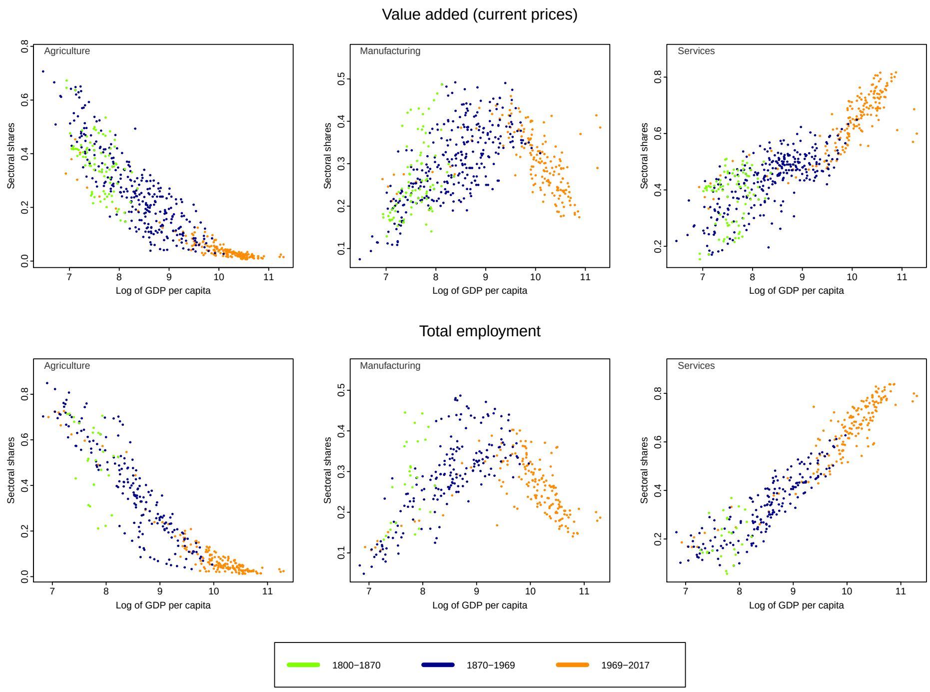

Figure 3: Sectoral shares vs. GDP per capita, grouped by industrial revolutions periods (all countries for which data are available before 1950)

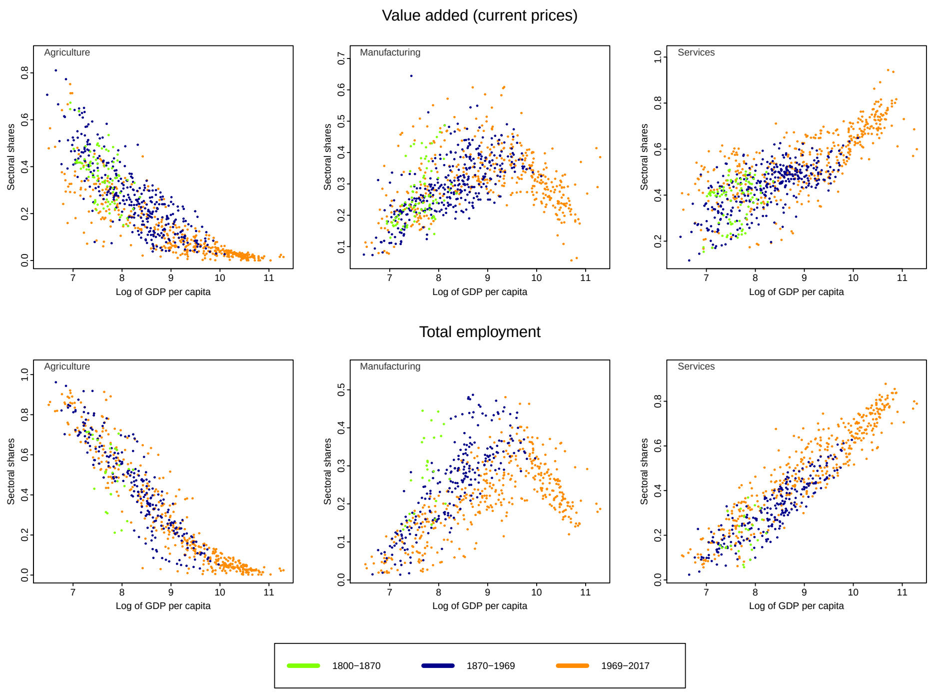

Figure 4: Sectoral shares vs. GDP per capita, grouped by industrial revolutions periods (including less developed countries with observations after 1950)

Dependent variable	**Forecast values at:**				
	2000$	5000$	15000$	30000$	50000$
AGRVA	0.40	0.25	0.14	0.11	0.11
MANVA	0.24	0.31	0.30	0.24	0.17
SERVA	0.34	0.43	0.55	0.64	0.72
AGREMP	0.56	0.34	0.15	0.07	0.03
MANEMP	0.15	0.26	0.27	0.20	0.12
SERVEMP	0.29	0.40	0.58	0.73	0.85
SCHOOL	2.14	3.87	6.46	8.37	9.92
LIFEXP	43.55	53.36	62.44	66.67	69.03
URBANIZATION	0.58	0.68	0.79	0.85	0.90

Notes: Income per capita in expressed in 2011 US$ (multiple price benchmarks). Forecast values refer to a representative country with median population size and controlling for country fixed effects.

Table 3: Variable forecasts as a function of different income levels

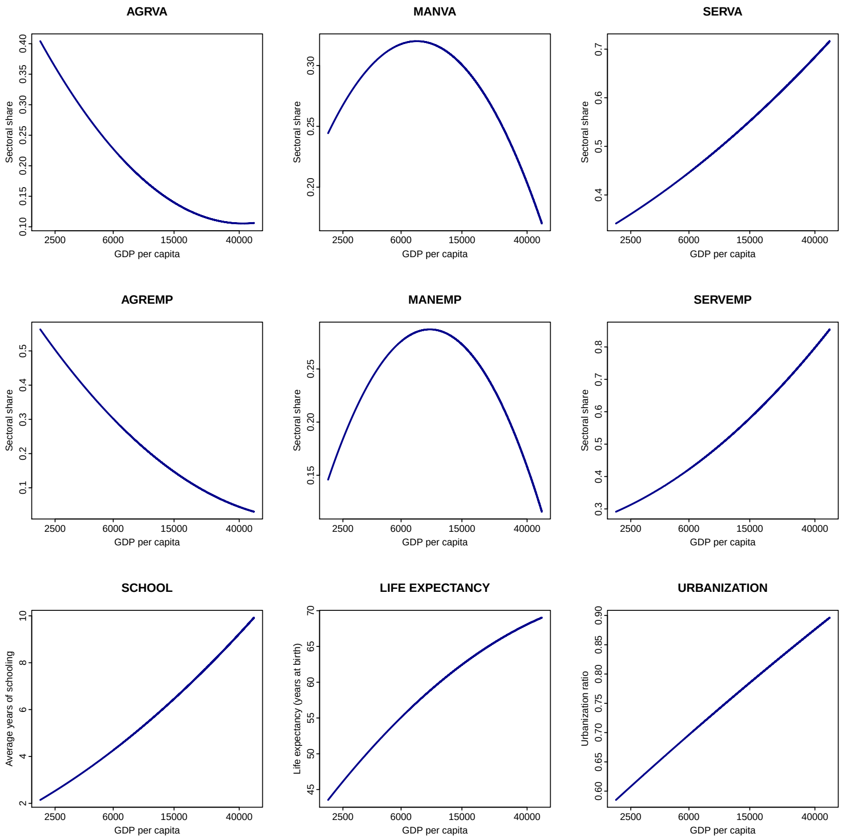

Figure 5: Simulated dynamics of sectoral shares and modernization variables (assuming median population size and removing fixed effects)

from the unfolding of the three industrial revolutions (cf. Fig. 4).

4 Manufacturing as an engine of growth?

The analysis in the previous section suggests that industrialization (understood as the shift of labour force from agriculture to manufacturing) is a necessary condition for triggering economic development. With the exceptions of few resource-rich countries and small open economies, no country has managed to take off without expanding its manufacturing sector (Szirmai, 2012). Drawing on this type of evidence, some authors have postulated the general role of manufacturing as an engine of growth operating at all development levels (Kaldor et al., 1967; Cornwall, 1977).[8] This hypothesis is grounded on a set of compelling empirical and theoretical arguments and, therefore, it has exerted a strong influence on development economists over the last decades. First of all, from an historical point of view, evidence largely suggests that most of the technological innovations originate within the manufacturing sector (Landes, 1969; Rosenberg, 1982; Freeman and Louçã, 2001), while services are characterized by relatively low rates of technical change (Baumol, 1967).[9] Manufacturing also exhibits a scope for dynamic and static economies of scale significantly larger than in traditional or agricultural and service activities as well as wide opportunities for the adoption of capital-embodied technologies (Young, 1928; Myrdal, 1957; Kaldor et al., 1967; Cornwall, 1977). Forward and backward linkages across firms and sub-industries are stronger in the industrial sector implying fast propagation of demand and technological shocks via demand linkages and knowledge spillovers (Hirschman, 1958). Moreover, it has been recently put forward that technological spillovers in manufacturing are large also across national boarders offering wide opportunities for unconditional convergence of laggard economies (Rodrik, 2012, 2016a). Finally, especially at low stages of development, there are margins for exploiting the increasing demand of manufactured goods stemming from rising income levels (i.e. the Engel's law).

The "engine of growth" hypothesis can be tested in different samples using a variety of empirical techniques. The selection of countries included in the analysis clearly matters greatly since advanced nations, as already discussed, are nowadays dominated by the service sector and display a distinct behaviour with respect to laggards. Results therefore can vary largely depending on the characteristics sample considered, i.e. whether it is composed by rich- or middle- and low-income countries. In terms of statistical approaches we may distinguish between studies relying on descriptive evidence, econometric excercises or growth accounting methods. From a purely descriptive perspective, Szirmai (2012) contrasts the levels and growth rates of productivity in manufacturing vis-à-vis other sectors in a sample of developing and developed countries (excluding African economies). While productivity levels generally tend to be higher in manufacturing (see McMillan et al., 2014, for a similar result), faster growth is often observed from the 80s in agriculture, especially in developed countries.[10] In other terms, shifting resources from traditional activities to industrial ones provides a static "structural change bonus" but no generally dynamic gains.

A second stream of literature introduces sectoral shares in growth regressions where the dependent variable is a proxy of aggregate productivity growth. In comparison to growth accounting techniques, this approach has the advantage of estimating the net contribution of changing sectoral shares, including external effects and spillovers, but is affected by the well-known econometric shortcomings of growth regressions.[11] Fagerberg and Verspagen (1999) present first estimates in this direction which hint at a significant role limited to less developed countries. Their approach has been extended in Fagerberg and Verspagen (2002) where they estimates the growth effect of manufacturing and sectoral shares in a semple of 29 (mostly advanced) countries, allowing for three time slope dummies at 1972, 1983 and 1995. Their results suggest a strong contribution of manufacturing in the earlier period, associated to the catch up phase of OECD countries, while a declining importance in recent times, probably due to the emergence of ICT-intensive service activities. Along similar lines, Szirmai and Verspagen (2015) investigates the same relationships in a larger sample of 92 countries including many developing ones.

[8] An extended survey of the arguments and the literature on the "engine of growth" hypothesis is found in (Szirmai, 2012).

[9] The classical view of services as less dynamic activities has been recently questioned in light of the emergence and diffusion of ICT technologies. For a rehabilitation of agriculture and of "biological innovation", see Olmstead and Rhode (2008). A detailed discussion is provided in the next Section.

[10] Szirmai (2012) interprets such result as originating from the so-called "industrialization of agriculture", i.e. rising capital intensities and declining shares of value added in the sector. This entails a fall in persons engaged more rapid than the one in output.

[11] For in depth critiques of growth regressions see e.g. Durlauf et al. (2005) and Pritchett (2000).

The findings point to a generally modest effect of manufacturing shares on growth when time observations are pooled. However, when considering different sub-periods, a positive impact is found only for 1970-1990 while, interestingly, there are respectively positive and negative interactions effects with human capital and income gaps. This, in turn, hints at a strong growth-promoting role in laggard countries with a well-educated labour force. Rodrik (2009) presents regressions for 5-years intervals in a panel dataset controlling for trade shares as well as country and yearly fixed effects. His estimates are consitent with the general conclusion from the literature according to which rising manufacturing shares matters for growth, especially in less developed areas of the world. The analysis by Su and Yao (2017) focuses on middle-income countries and uses three different econometric approaches – Granger causality tests, cross-sectional regressions and panel regressions – concluding that manufacturing expansions trigger the growth of service activities and, thus, they still act as the key engine of development. In tune with these findings, Marconi et al. (2016) exploit a dynamic panel, including countries at all stages of development, to test the two fundamental Kaldorian laws relating manufacturing to income and productivity growth (Kaldor, 1966). They confirm that both the Kaldor's law are supported by the data and that manufacturing exports, in particular, are capable to spur GDP and productivity increases.

Taking cue from the recent interest on the determinants of medium run fluctuations (Pritchett, 2000; Hausmann et al., 2006), some studies examines the effect of structural change on specific growth episodes. Szirmai and Foster-McGregor (2017) includes manufacturing shares as explanatory variables for the duration of positive episodes and the probability of their end. High manufacturing shares, together with a diversified structure of production, turn out to be associated with longer duration of growth phases and, thus, they affect countries ability to sustain growth over the long run.[12] A different perspective is found in Timmer and de Vries (2009) who use productivity decomposition methods to measure the contribution of various sectors during acceleration episodes. They find that, notwithstanding the general positive effect of manufacturing, the largest part of growth during accelerations is explained by productivity gains within market services. In the same fashion, other works highlights the dominant role of non-traditional service activities over manufacturing ones (Dasgupta and Singh, 2005, 2006; Ghani and O'Connell, 2014). For instance, it has been pointed out that, to a large degree, the disappointing European growth performance during the last two decades, in comparison to the US, may be the result of slow accumulation of ICT capital in market services (Inklaar et al., 2005; Timmer and Van Ark, 2005; Inklaar et al., 2008; Van Ark et al., 2008). To account for this evidence, Lavopa and Szirmai (2018) propose to shift the emphasis from manufacturing to the broader "modern sector", defined as to include industry and tradable services (e.g. Telceomminications, Transports).

Another source of skepticism comes from the evidence on "premature deindustrialization" whereas several developing countries are experiencing falls in manufacturing shares at much lower levels of income per capita (Dasgupta and Singh, 2006; Ghani and O'Connell, 2014; Rodrik, 2016b; Callaghan et al., 2019). These contributions tend to stress the shrinking opportunities for manufacturing-led growth and, in consequence, the need for poor countries to re-consider their development strategies, placing more emphasis on other modern activities. Nevertheless, this argument has been questioned in light of new evidence presented by Haraguchi et al. (2017). The paper shows that the premature drops in manufacturing shares are not due to changing structural characteristics of the sector, but are instead related to the increasing concentration of industrial activities in a small group of fast-growing economies. According to the authors, the prescription for backward nations is to emulate the path followed by today's emerging countries and to exploit future opportunities arising from their next deindustrialization phase.

To sum up, although industrialization probably still represents a necessary stage of development for low- and middle-income economies, the evidence concerning the "strong" form of the hypothesis of manufacturing as the engine of growth is mixed. In particular, focusing on rich nations, manufacturing appears to have lost part of its dynamism as compared to ICT-intensive service sectors and to modern agriculture. Of course, this may well be the result of innovations originating in the industrial sector (e.g. semiconductors) which then spread to other activities, making further innovations possible (e.g. new software). This results tend to suggest the need for going beyond the conventional contrast between manufacturing and the other traditional activities. To account for such new findings, in the next Section we move forward to the analysis of sector-specific patterns of innovation and technical change at finer levels of aggregation.

[12] Aizenman and Spiegel (2010) make a similar point on the impact of diversified production structure on growth take offs.

5 Sectoral patterns of innovation and structural change

As noted by Kuznets, the traditional emphasis on structural change looking at agriculture, manufacturing and services is not able to capture in detail the connection between structural transformation and technical change. This involves a more disaggregated perspective which will focus on patterns of technical change at sectoral level and on the interactions between technical advances in different sectors. On this issue, Kuznets noted: "Since the high and accelerated rate of technical change is a major source of the high rates of growth of per capita product and productivity in modern times and is also responsible for striking shifts in production structure, it is frustrating that the available sectoral classification fail to separate new industries from old, and distinguish those affected by technological innovations" (Kuznets, 1971, p. 315; cited in Rostow, 1990, p. 355).

Along somewhat similar lines, several scholars in the field of innovation studies have emphasized the substantial heterogeneity characterizing the features of the innovative process in different sectors (Nelson and Winter, 1977; Dosi, 1982; Freeman et al., 1982; Perez, 2003; Pavitt, 1984) trying to design characterizations of sectoral patterns of innovation that could be also useful for the study of long-run structural transformation. A first key aspect concerns the extent to which specific industries can reap the benefits stemming from new techno-economic paradigms. As stated before, the emergence of radical innovations exhibiting high degrees of pervasiveness and complementarity opens up new sets of technological opportunities, which are exploited differently depending on sector-specific characteristics. Most importantly, industries showing a strong relatedness in terms of knowledge base and capabilities (with respect to the cluster of new technologies) are more likely to follow dynamic trajectories, providing a great contribution to aggregate productivity growth. Of course, such patterns entails strong disruptive effects on the economic system, as originally put forward by economic historians (Kuznets, 1930; Burns, 1934; Schumpeter, 1939). In specific historical contexts, as the new group of technologies are introduced and diffused in the economy, old industries, i.e. those not directly related to the new paradigm, may come to maturity or be replaced by emerging sectors. The latter usually provide a disproportional contribution to overall productivity growth, driving countries future growth performances. In turn, this is reflected in different phases of the so-called "industry life-cycles" (Gort and Klepper, 1982; Klepper, 1996), each associated to different scopes for further innovations and growth potentials.[13]

Motivated by such a great deal of sectoral heterogeneity, a large literature on sectoral patterns of innovation has emerged during last years. On the one hand, some case studies provide detailed accounts of performances and trajectories of isolated industries (Dosi, 1984; Bresnahan and Malerba, 1999; Mazzucato et al., 2006; Malerba and Orsenigo, 2015).[14] On the other, from a comparative perspective, some works focuses on the identification of cross-sectoral and cross-country differences along various domains (e.g. technology, institutions).

Among the latter strand of research, a key question concerns the linkages between sector-specific characteristics, differential innovation trajectories and productivity growth rates. In this respect, it is useful to start with the broad notion of Sectoral Innovation System (SIS) which is defined as "the set of new and established products for specific uses and the set of agents carrying out market and non-market interactions for the creation, production and sale of those products" (p. 250, Malerba, 2002). A SIS is composed by the firms operating in the sector, other relevant players (e.g. organizations, individuals), the structure of network interactions among agents, the knowledge base, the institutional framework in which agents behaviour is "embedded", the demand conditions as well as the processes governing competition and market selection. More precisely, the interactions among different elements of a SIS defines the sector-specific Technological Regime (TR) which is seen as the dominant driver of industry evolution. The concept of TR was originally introduced by Evolutionary economists (Nelson and Winter, 1982; Winter, 1984) to describe the environment in which firms' innovative activities take place along some key features such as: the cumulativeness and appropriability conditions, the level of technological opportunities and other factors of industrial dynamics.[15] A popular distinction in the literature is between the so-called Schumpeter Mark I and Schumpeter Mark II (Malerba and Orsenigo, 1995). The former regime

[13]Of course, phases of the life cycle also differs along various other characteristics, e.g. market structures, competition regimes, entry and exit dynamics.

[14]From a theoretical point of view, history-friendly models have been developed to replicate the observed historical records of a given sector (Malerba et al., 1999; Malerba and Orsenigo, 2002).

[15]Notice that one should not identify the TR exclusively with the technological intensity of the sector. Industries with similar technological contents may follow radically alternative trajectories as a result of the differences in the structure of their SIS and TR. An illustrative example of such phenomena is provided by Mani (2009) which analyses the case of pharmaceuticals and telecommunication equipment in India.

is characterized by relatively low entry costs and innovations are primarily carried out by new firms which, if successful, typically replace incumbents. On the contrary, in Schumpeter Mark II industries, barriers to entry provide a cumulative innovative advantage for existing firms. Several works attempt to identify different TR and to make a link with sectoral performances (Breschi and Malerba, 1997; Breschi et al., 2000; Marsili and Verspagen, 2002; Malerba and Orsenigo, 2015; Park and Lee, 2006). From an econometric point of view, early contributions tested the role of isolated variables (e.g. R&D intensities and spillovers) in explaining industry productivity growth while, more recently, the emphasis has shifted on multi-dimensional models including some elements defining SIS and TRs as well as other relevant features (e.g. trade openness, market extent).[16] In particular, Castellacci (2007) suggests that the links between TRs and productivity growth change across sectors depending on whehter they display Schumpeter Mark I or Schumpeter Mark II patterns. Fontana et al. (2012) corroborates such distinction by showing that breakthrough inventions tend to take place mostly in industries characterized by Schumpeter Mark I environments.

More generally, results from the literature on TRs and sectoral performances suggest positive direct and indirect effects associated to technological (e.g. R&D, patents and technological opportunities) and educational (e.g. skills and human capital) variables while, interestingly, appropriability conditions and market size seems to operate in the opposite direction (Castellacci, 2007).

Another related approach, pioneered by Pavitt (1984), aims to provide taxonomies of sectoral technological patterns on the basis of firms' innovation sources, strategies and user-producer relationships. Rather than focusing on technological and institutional regimes, here the emphasis is on the process of creation and diffusion of new ideas and products. A crucial aspect, therefore, concerns the input-output relationships existing across innovative firms operating in different sectors, on the linkages with general scientific advances and on the ability to generate innovations internally. Pavitt (1984) identified four dominant classes: *Science-based industries* are characterized by large firms relying on internal R&D and evolving in close connection to advances in scientific knowledge; *Specialized supplier industries* are populated by, mainly small or medium-sized, producers of machinery and tools embedding process innovations as well as forms of tacit knowledge; *Supplier-dominated industries* are mainly traditional sectors producing final goods in which typically adopt technologies developed elsewhere in the economy; finally, *Scale-intensive industries* are sectors associated to the Fordist era of mass production where scale economies are prominent and R&D is performed in house or in cooperation with specialized suppliers.[17] It has been conjectured that the emergence of each sectoral class can be linked to different historical phases of capitalist development (Archibugi, 2001). Table 4 reports the typical sectors in each category and the associated phase of development.

The availability of data from Community Innovation Surveys (CIS) has made possible further refinements of the original Pavitt's taxonomy (Evangelista et al., 1997; Evangelista, 1999; Mairesse and Mohnen, 2002; Bogliacino and Pianta, 2016). However, early classifications tend to be uniquely concerned with manufacturing activities. As discussed in the previous Section, such choice has its origin in Baumol's traditional view of manufacturing as the dominant *locus* of technological innovation and of services as productivity stagnant activities (Baumol, 1967). Clearly, radical discoveries in the area of Information and Communication Technologies (ICTs) have called into question such perspective as major advances along the new paradigm have allowed for productivity increases in existing services (e.g. finance, engineering) and revealed the great potential for dynamism of brand new activities (e.g. software, consultancy, mobile networks). The rise of the latter has been favoured by major organizational changes of the post-Fordist era whereas, a continuous outsourcing process, has led to a disintegration of traditional manufacturing companies into complex network-based entities in which activities formerly conducted internally are now provided by specialized service suppliers. Gallouj and Savona (2009) show that the measurement errors and definition problems have largely affected the conventional view on service innovation. Taking into account the specificities of service innovation activities leads to a new perspective which acknowledges the scope for sustained productivity gains even in the service part of the economy. Motivated by these insights – and by the dominant role exerted by services in advanced economies – a body of literature has emerged proposing new taxonomies of

[16]These analysis are typically carried out for a cross-section of industries from different countries. For a survey focused on the impact of R&D variables on productivity see Los and Verspagen (2004) while a comprehensive discussion of the literature is found in Castellacci (2007).

[17]This taxonomy has been used as a guideline for several micro and meso empirical investigations. Some examples include Dosi et al. (1990), Padoan (1998), Dosi et al. (2008), Bogliacino and Pianta (2010). For an early survey of the literature see Archibugi (2001).

innovation modes in services (Gallouj and Weinstein, 1997; Evangelista, 2000; Miozzo and Soete, 2001; Evangelista and Savona, 2003; Drejer, 2004; Camacho and Rodriguez, 2008). Pavitt himself, in a later joint contribution extended is own classification to incorporate the broad category of *Information Intensive* service industries (Tidd et al., 2005). The latter includes, for instance: finance, telecommunications, retailing, consultancy and publishing. Firms engaged in these activities typically feature in-house software and IT departments and interact with specialized suppliers of IT hardware to develop systems for organizing and processing information, the final being the provision of knowledge-intensive personal and business services. Instead, Castellacci (2008) provides a more comprehensive taxonomy which proposes a unifying framework, avoiding the fragmentation between manufacturing and services, as well as a more detailed classification of service industries. The model adopted has two main dimensions: the role assumed by each industry as supplier or user of innovations, i.e. its position in the input-output network of the economy; the level of technological sophistication which includes a broad definition of technical capabilities together with the ability to generate innovations internally. A graphical representation of the model is provided in Figure 6. The resulting taxonomy includes four major classes, each composed by two sub-categories:

- **Advanced knowledge providers:** These industries are positioned at the bottom of the vertical supply chain being providers of technological knowledge for other sectors. Firms populating these sectors are typically small or medium sized and master sophisticated technical competences. Innovation is carried out internally and in cooperation with clients. Within this category we find Pavitt's *specialized suppliers* (e.g. machine-producing sectors) and the *knowledge-intensive business services* (e.g. R&D, consultancy).

- **Infrastructural services:** Also these industries are located at lower stages of the production chain. They are concerned with the production of intermediate products and services which play the role of supportive infrastructures for companies engaged in other activities. Differently from the previous class, the average firm size tend to be large and the level of technological sophistication is not particularly high as they rely on the provision of machinery and knowledge from external suppliers. Here we can distinguish between *physical infrastructures* (e.g. transport and wholesale trade) and *network infrastructures* (e.g. telecommunications and finance).

- **Mass production goods:** the core of the Fordist system of production that includes *scale-intensive* (e.g. motor vehicles) and *science-based* (e.g pharmaceuticals, electronics) industries. As in the original Pavitt's classification both are close to the final part of the supply chain and are characterized by substantial technological capabilities. While the former tend to rely both on in-house R&D and, especially nowadays, on external collaborations with advanced knowledge providers, the latter are more dependent on scientific discoveries achieved by research institutions.

- **Personal goods and services:** These sectors are populated by (generally small-sized) enterprises which provide goods and services to final users and are characterized by a low technological content, being heavily dependent on external knowledge generated by their suppliers. Innovations in these areas takes mostly the form of slow incremental improvements in the production processes and in product quality. Under this label fall *supplier-dominated* goods (e.g. food and textiles) and services (e.g. retail trade, hotels and restaurants).

The vast cross-sectoral heterogeneity documented here clearly bears the general conjecture, put forward in previous Sections, according to which structural transformations entail a large potential for productivity growth via the differential rates of technical progress across industries. Growth-promoting activities located at the bottom of the innovation supply chain do not belong exclusively to the industrial sector but also include a bunch of hi-tech market services (e.g. technical consultancy, R&D, telecommunications).

On the grounds of such evidence, the following Section aims to provide an overview of the structural trajectories followed by countries at different development levels in the post-WWII period.

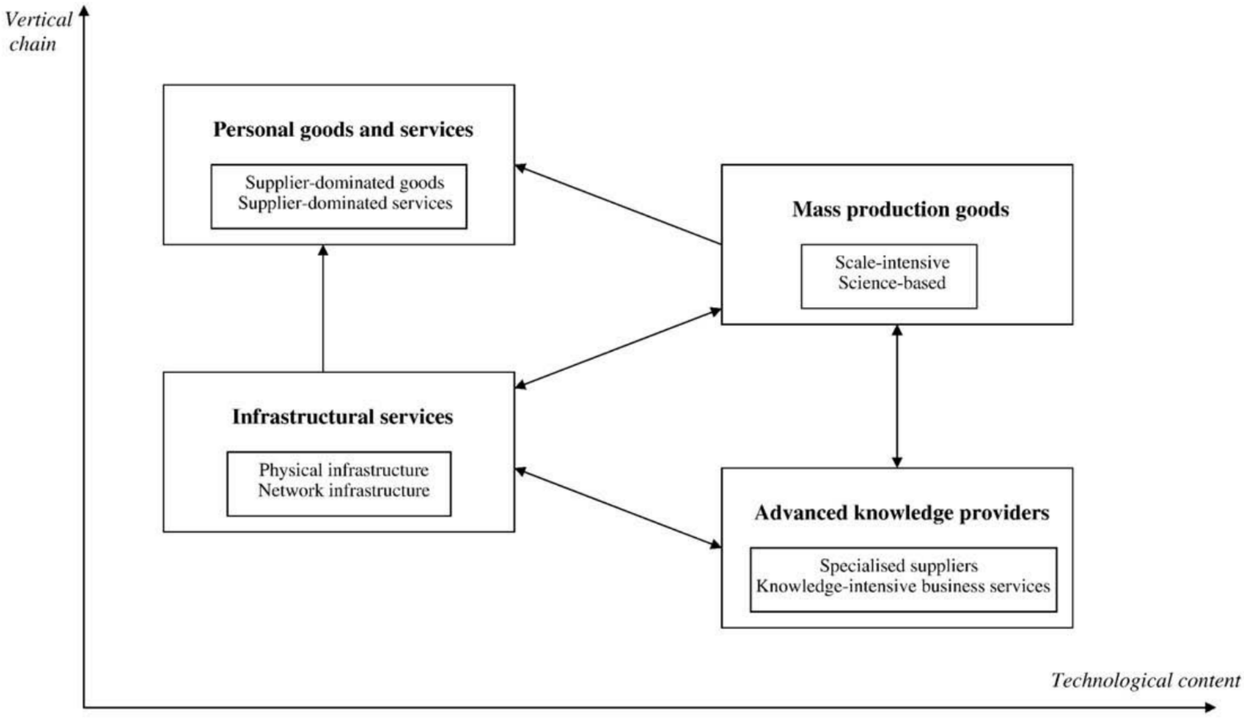

Figure 6: Technological and economic linkages in Castellacci's taxonomy

Phase of development	Typical industries	Pavitt's category
First industrial revolution (1^{st} phase)	Textiles; Pottery	Supplier dominated
First industrial revolution (2^{nd} phase)	Mechanical engineering; Machine tools	Specialized suppliers
Second industrial revolution (1^{st} phase)	Chemicals; Electrical machinery;	Science based
Second industrial revolution (2^{st} phase)	Automobiles; Consumer durables; Plastics	Scale intensive
Third industrial revolution (3^{rd} phase)	Microelectronics; Computers; Software; Internet	Information intensive

Source: Archibugi (2001).

Table 4: Pavitt taxonomy and the three industrial revolutions

6 Structural change patterns and productivity growth

To assess empirically the precise connection between structural change and aggregate productivity growth one needs sectoral data on factor use and output at sufficiently low aggregation levels. Data of this kind are available from the post-WWII period for a large sample of countries. Of course, data quality and coverage varies significantly from rich to developing countries. For the former, researchers involved in the KLEMS project (O'Mahony and Timmer, 2009) have constructed a database including figures for value added and 5 types of input variables in 34 industries, from 1970 onwards. Data for developing countries are typically limited to 10 major sectors and are more likely to be affected by measurement errors due to the large presence of the informal sector (Timmer and de Vries, 2009). Based on these datasets, several empirical papers have investigated structural change patterns in different group of countries and the potential impact on aggregate income and productivity growth. These studies shed a light on successful development cases and best practices as well as parallel failures and missing opportunities providing, in this way, relevant prescriptions for national policy makers. In this section we first provide an overview of the key findings from this literature for five major groups of countries. Then, we present some brand new evidence linking productivity decomposition methods to the literature on sectoral innovation patterns.

6.1 The evidence from 5 major country groups

USA and Western Europe. As widely documented, Western Europe experienced a phase of rapid catching up with respect to the US after World War II. This period was characterized by massive imitation of foreign technologies supported by institutions of the Fordist type and by a reletively well-educated labour force (Crafts et al., 1996). Structural change during this period contributed positively to overall productivity growth by shifting resources mainly towards sectors producing mass production goods (Crafts et al., 1996; Van Ark et al., 2008). In a growth accounting framework, Temple et al. (2001) computes reallocation effects during the European boom ranging from a tenth to a seventh of total productivity growth with stronger effects for countries such as Italy and Germany. After 1970, both Western Europe and the US experienced a substantial growth slowdown followed by divergent dynamics from the 90s. Indeed, during the last two decades Europe entered into a phase of relative stagnation while productivity in the US economy accelerated. A series of works document this pattern and attempt to pin down the potential driving forces (Inklaar et al., 2005; Timmer and Van Ark, 2005; Inklaar et al., 2008; Van Ark et al., 2008; Jorgenson and Timmer, 2011). Among them, differential sectoral trajectories have been showed to be relatively important. First, Jorgenson and Timmer (2011) report an increasing relative importance of ICT producing industries and market services in the US which now display higher productivity than traditional manufacturing activities (both in levels and in growth rates).[18] In both areas Europe is lagging behind experiencing low investment rates and a slower evolution of productivity. The so-called "shift-share" analysis reveals that much of the divergent dynamics can be accounted by improvements within these ICT-intensive activities rather than reallocation effects (Jorgenson and Timmer, 2011).

East Asia and Japan. East Asian countries stands out as exceptional cases for their rapid development during last 50-60 years. Japan was the first country to join the club of catching up European economies in the 50s and it was followed a decade later by South Korea, Taiwan, Singapore and Hong Kong.[19] Japanese growth encountered a sudden stop at the beginning of the 90s which resulted in two subsequent lost decades in which both the national product and the productivity stagnated. On the contrary, with the exception of the 97 financial crisis, growth proceeded at sustained rates until nowadays for the other "Asian Tigers".

How do such exceptional performances relate to structural transformations? Although there is an open debate, an increasing consensus seems to interpret the Asian miracle, in tune with a Technology-gap perspective (Abramovitz, 1986; Gerschenkron, 1962), as the result of radical changes in the economic structure aimed at developing competitive advantages in technologically dynamic sectors (Amsden, 1989; Nelson and Pack, 1999).[20]

[18]Within market services there is considerable heterogeneity. While distribution activities display fast growth rates, financial and personal services are characterized by a more sluggish dynamics.

[19]For the sake of clarity here we refer to the experiences of Japan and of the four major Asian tigers. To a moderate extent, the evidence discussed may be generalized also to second waves of Asian industrializers (e.g. Malaysia, Indonesia). For more detailed accounts of countries' idiosyncratic experiences we remind the reader to the literature presented in this paragraph.

[20]Alternative explanations tend to emphasize inputs and capital accumulation rather than improvements in Total Factor Produc-

This process entailed learning efforts in the private sector to develop adequate production and organizational capabilities, educational achievements in the creation of managerial and scientific skills and coordinating role played by the state in the form of export-oriented industrial policies (Amsden, 1989; Wade, 1990; Kim, 1993; Nelson and Pack, 1999; Kim and Nelson, 2000). As in other instances, the contribution of structural change can be measured using accounting techniques. A series of works finds a strong positive effect of structural change (around 30 % of total productivity growth) in the early phases of Asian development and an increasing role of within-sectors productivity advancements in later stages, as the scope for mobilizing resources towards modern activities reduced (McMillan et al., 2014; Timmer et al., 2015a; Foster-McGregor et al., 2016). Notwithstanding the decreasing contribution of structural change, van Ark and Timmer (2003) document substantial productivity gains as a result of within-manufacturing shifts from labour-intensive to ICT-intensive industries during the transition from middle- to high-income levels.[21] Interestingly, Asian countries did not experience a negative impact of sectoral re-allocations in dynamic terms, a pattern which is instead observed in Africa and Latin America (Timmer et al., 2015a; Foster-McGregor et al., 2016). Timmer et al. (2015a) show that this stems from the ability to achieve sustained growth rates in market services – in particular in trade and distribution activities – which have steadily increased their importance in all regions over the last two decades.

Timmer et al. (2015a) also offers insights on the Japanese slowdown in comparison to other Asian experiences whilst the largest gap with fast-growing neighbours appears to be in the within component. The contribution of structural change terms instead are in line with the regional average.

Latin America. Among less developed nations, Latin America was the most industrialized region in the 50s (Szirmai, 2012; Timmer et al., 2015a). Nevertheless, countries in this region never managed to embark on a process of self-sustained industrialization. This resulted in systematic failures to catch up with leader nations as well as in turbulent growth paths characterized by accelerations episodes and subsequent crisis (Hausmann et al., 2005; Pritchett, 2000). Among the explanations of the failure put forward in the literature, economists tend to stress factors such as bad institutions, lack of investments in physical and human capital as well as the perverse interaction between natural endowments and specialization trajectories towards labor- and resource-intensive goods (e.g. Solimano and Soto, 2006; Restuccia, 2013; ECLAC, 2017). This last aspect is particularly important for the Structuralist tradition (Prebisch et al., 1950; Cimoli and Katz, 2003; Cimoli and Correa, 2005; Cimoli and Porcile, 2013) that identifies policy failures in triggering upgrades of the productive structures as the biggest bottleneck to development. Hence, according to this interpretation, structural change lies at the center of Latin American problems. Indeed, several countries from the 70s have experienced "premature deindustrialization", i.e. a fall in manufacturing shares at relatively low income levels (Rodrik, 2016b). Consequently, the short-lived periods of accelerations have been manly driven by temporary productivity spurts in market services rather than in manufacturing (Timmer and de Vries, 2009). A recent contribution by Timmer et al. (2015a) also shows that during the period 1960-1975 Latin American economies were experiencing growth-enhancing structural change as a result of rising industry shares. This pattern reverted in subsequent years and especially after the 90s where the contribution of the re-allocation component becomes strongly negative (McMillan et al., 2014; Timmer et al., 2015a). In particular, differently from what observed in East Asia, Latin American nations accumulated a large gap in terms of productivity growth in market activities (e.g. distribution and retail trade) which led to high dynamic losses (Timmer et al., 2015a).

Sub-Saharan Africa. Sub-Saharan countries display similar patterns to Latin American ones. Set aside few notable exceptions (e.g. Botswana, Mauritius), also these economies experienced an endemic lack of growth in productivity and living standards in the post-war period. A positive effect of structural change in the region is found only for the earlier periods (1950-70) and, more moderately, after 1990, while the intermediate years are characterized by negative productivity growth rates (in the aggregate) and a strong negative impact of structural change (McMillan et al., 2014; Timmer et al., 2015a). Such reversal of negative performances observed in the 90s, notwithstanding its (mainly) service-driven nature, has led to some optimistic views on the future of African growth (McMillan et al., 2014). This is in contrast to other accounts that have expressed skepticism on the possibility of a service-led growth strategy emphasizing the presence of large dynamic losses (coexisting with

tivity (e.g. Young, 1992; Krugman, 1994). A critical discussion of this interpretation is provided by Felipe (1999).

[21] This evidence is in contrast with other studies stressing the prevalence of manufacturing-wide effects over within-manufacturing re-allocations (Timmer and Szirmai, 2000; Fagerberg, 2000).

static gains) in service activities (Timmer et al., 2015a; De Vries et al., 2015). In a similar vein, Diao et al. (2017) analyze growth booms in Africa and find substantial heterogeneity in structural change patterns during these episodes. Successful and long-lasting expansions (Botswana, Ghana and Mauritius) are associated to fast productivity growth within the modern part of the economy whilst structural change played a role only for Mauritius. On the contrary, growth experiences that raise more concerns (e.g. Ethiopia, Tanzania) are those in which growth-enhancing structural re-allocations are accompanied by stagnant or declining productivity in the modern sector.

The BRICS. The acronym BRICS refers to a group of emergent countries that have gained increasing attention over the last two decades. The group includes Brazil, Russia, India, China and South Africa. These economies now account for a large part of world GDP and exports as they have increased significantly their participation in global value chains. Nevertheless, growth performances among BRICS are rather heterogeneous both in terms of GDP levels and GDP per capita. The volume by Naudé et al. (2015) collects a series of contributions addressing various aspects of structural transformation in BRICS. The main insight is that the foregoing heterogeneity maps into different structural trajectories followed by individual countries. China and, to a lesser extent, India appear to have experienced a significant expansion of capital-intensive manufacturing activities while Brazil, Russia and South Africa are instead moving towards resource- and service-based specialization patterns. Clearly, such divergent trajectories reflect different degrees of economic success whereas China and India are also catching up with the world leaders at faster rates than other BRICS. Such broad impression is supported by the shift-share analysis presented in De Vries et al. (2012). The authors report a strong positive contribution of resource shifts between sectors only for China, India and, to a lower extent, for Russia. In Brazil, the only positive effect of structural change comes from the increasing formalization of the economy.

6.2 Productivity decomposition using sectoral innovation classes

Notwithstanding several attempts to decompose aggregate productivity into idiosyncratic sectoral components, the criteria used to build sectoral aggregates seem to overlook the results from the literature on sector-specific innovation patterns discussed in Section 4. A notable exception is represented by Castaldi (2009) which combines the shift-share approach and a sectoral innovation taxonomy. Besides the standard distinction between agriculture, services and manufacturing (McMillan et al., 2014), some papers propose to discriminate also between ICT activities, market and non-market services (Inklaar et al., 2005; Timmer and Van Ark, 2005; Inklaar et al., 2008; Van Ark et al., 2008; Jorgenson and Timmer, 2011). Here instead we directly take into account the insights from innovation scholars emphasizing the diversity of technical change patterns at the sectoral level. More specifically, we use the Castellacci's taxonomy presented in the previous Section to isolate the contribution of sectors characterized by different innovation patterns. As the taxonomy acknowledges the diversity of user-producer relationships across sectoral classes it also allow us to make some conjectures on the potential co-evolutionary processes existing among them. This implies a relevant advantage since the shift-share analysis based on more standard classifications offers little to say in terms of external effects and interactions across sectors.

Table 5 displays details on the classification used which is taken from Castellacci (2008). In particular, it distinguishes between *Advanced knowledge providers* (ADVknowl), *Mass production goods* (MASSprod), *Supportive infrastructure services* (INFRAserv) and *Personal goods and services* (PERSgoods&serv).

Let us start by plotting the evolution of labour productivity for each sectoral class in 7 major regions (cf. Figure 7). Data reveals large cross-country heterogeneity in sectoral productivity trajectories. Canada, for instance, has managed to develop a dynamic infrastructure service sector but also exhibits disappointing performances in the other three categories. The sluggish dynamics in the knowledge-providing sector may well account for the lack of growth in more supplier-dominated activities such as mass production and personal goods or services. On the contrary, in Asian countries and in the US, improvements in infrastructure services are also accompanied by gains in the *ADVknowl* group possibly pointing at a co-evolutionary process between the two categories. Similarly, the mass-producing goods industry closely evolves with the *ADVknowl* and *INFRAserv* classes as it largely draws on technological advances from both sectors. Such joint dynamics break down only in Japan and partially in Korea as a result of the 2007-2008 macroeconomic crisis which largely hit industries in the *MASSprod* area. Europe, instead, has performed relatively well in both infrastructures and mass production sectors but is

Description	Abbreviation	NACE Rev. 2 codes
Advanced knowledge providers (*incl. Electrical & optical equipment; Machinery and equipment n.e.c.; IT & other information services; Professional, scientific, technical, administrative & support service activities)*	ADVknowl	26-28; 62-63; M-N
Mass production goods (*incl. Coke and refined petroleum products; Chemicals and chemical products; Rubber and plastics products, and other non-metallic mineral products; Basic metals and fabricated metal products, except machinery and equipment; Transport equipment)*	MASSprod	19; 20-25; 29-30
Supporting infrastructure services (*incl. Wholesale trade; Transport and storage; Postal and courier activities; Telecommunications; Financial and insurance activities)*	INFRAserv	45-46; 49-52; 53; 61; K
Personal goods & services (*incl. Food products, beverages and tobacco; Textiles, wearing apparel, leather and related products; Wood and paper products, printing and reproduction of recorded media; Retail trade; Accommodation and food services)*	PERSg&s	10-18; 47; I

Table 5: Description of sectoral innovation classes as in Castellacci (2008)

also characterized by a stagnant productivity in knowledge-providing activities. Finally, with the exception of China, personal goods and services display the low growth rates and their patterns are generally disconnected from those in other activities.

To add further details to the picture provided so far, we now compute the contribution of the four sectoral innovation classes employing the shift-share analysis pioneered by Fabricant et al. (1942). Productivity is decomposed according to the following formula:

$$\Delta P(t_0, t_1) = \sum_{i=1}^{n} \Delta P_i(t_0, t_1) * \theta_i(t_0) + \sum_{i=1}^{n} \Delta\theta_i(t_0, t_1) * P_i(t_0) + \sum_{i=1}^{n} \Delta\theta_i(t_0, t_1) * \Delta P_i(t_0, t_1), \tag{2}$$

where P and θ stands respectively for sectoral productivity levels and employment shares while the usual Δ operator represents their variations between t_0 and t_1. The equation shows that sectoral contributions can be further decomposed in three components. The first term account for productivity advancements within single sectors holding constant initial employment shares. The second and the third terms instead refer to static and dynamic reallocation effects and therefore they pin down the contribution of structural change, i.e. whether it is growth-reducing or growth-enhancing.

Figures 8 and 9 display the results of the decomposition for Asian and North American countries vis-à-vis Europe. Results for individual countries are instead reported in Table B.2. The analysis is broken down into two sub-periods (2000-2007 and 2007-2014) to take into account the effects of the Great Recession. A first striking pattern concerns the relatively country-invariant rankings across sectoral groups. More knowledge-intensive classes (ADVknowl and INFRAserv) tend to show higher contributions while, as expected, the production of personal goods and services shows the lowest dynamism. Activities associated to mass production like science-based and scale-intensive manufacturing play a role especially in China and Korea which are large exporters in these areas. In tune with other contributions, we find that the within-class productivity gains generally provide the highest contribution to overall growth. However, results also suggest strong positive gains associated to structural change towards advanced knowledge providers in Asian countries and partially in Europe. Such positive effects cannot be captured by analysis that look only at the aggregate impact of structural change as they are often compensated by changes in the opposite directions from other sectors. Indeed, China is the only country in which the structural change component displays a positive sign for each sectoral category. This is not surprising since, as already discussed, the scope for achieving productivity gains trough reallocation is stronger during phases of rapid catching up. On the contrary, in countries at higher development levels, opportunities for growth-enhancing structural change seem to be associated exclusively to knowledge providing activities such

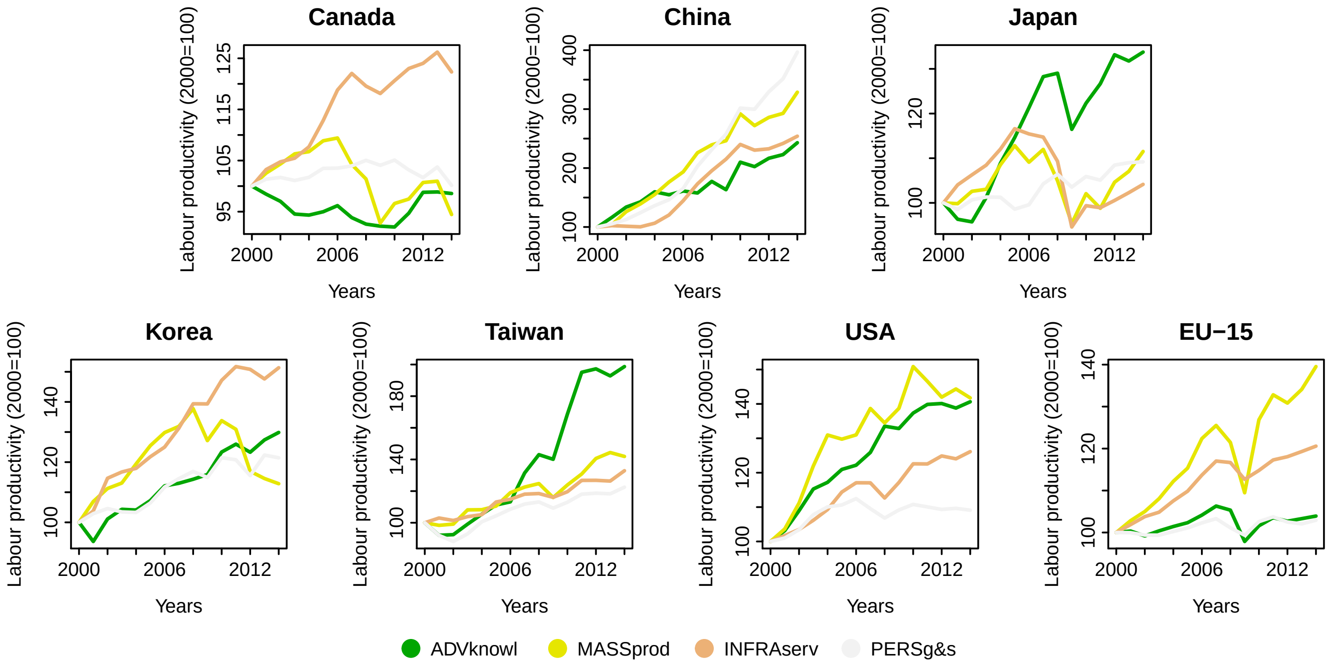

Figure 7: Labour productivity dynamics by sectoral innovation classes

as IT services, technical consultancy and specialized suppliers of machinery. A potential explanation for this pattern could be that many of the ICT-related industries are in the early stages of their life-cycle and, thus, they yet display large potential for increasing their relative size and productivity.

Also interesting is the comparative performance of US vis-à-vis Europe. Consistently with other empirical studies our results indicate that a large part of the differential productivity growth among the two regions is explained by the gap (around 3%) in the within component of knowlege- and ICT-intensive areas.

Some of the foregoing results survive to the impact of the global financial crisis (cf. Figure 8). First, the effect of the crisis is primarily found in the general slowdown of productivity within groups. The *ADVknowl* and *INFRAserv* categories appear to be the less hardly hit (with the exceptions of Europe and Japan) as they both exhibit relatively lower losses in within-sector productivity growth. Moreover, the larger room for growth-enhancing structural change in the *ADVknowl* group is confirmed also for the period 2007-2014 together with the European vulnerability in these particular activities, as reflected by the negative within component.

7 Conclusion

The relationship between structural change, technical progress and aggregate productivity growth has been at the core of several insightful conceptualizations of the process of modern economic growth such as those of Kuznets, Rostow, Dahmen and neo-Schumpeterian authors such as Freeman, Louca, Perez and von Tunzelmann.

In this chapter we contributed to this literature along various dimensions. First, we showed that the conjectures on the secular movements in the sectoral composition of the economy (i.e. the Petty-Clark law) are supported by the data. Second, the chapter provides an extensive review of the contributions linking structural change and sector-specific patterns of innovation to aggregate productivity growth. Finally, an empirical exercise merging shift-share analysis and sectoral innovation taxonomies has been presented. The results from the latter confirms that successful catch-up experiences (e.g. China) largely draw on structural transformation as a source of productivity growth. In advanced countries, instead, knowledge-intensive activities still provide wide margins for achieving productivity gains via both sectoral reallocations and within-sector technological advances.

At the methodological level, our analysis suggests that an important directions for further research is to move towards more disaggregated accounts that are able to capture both the sectoral heterogeneity of technical advance and the structure and transformation of the economic and technological linkages between industries. A promising step in this direction is made in this volume by Haraguchi and Amann (2019) which analyze productivity patterns

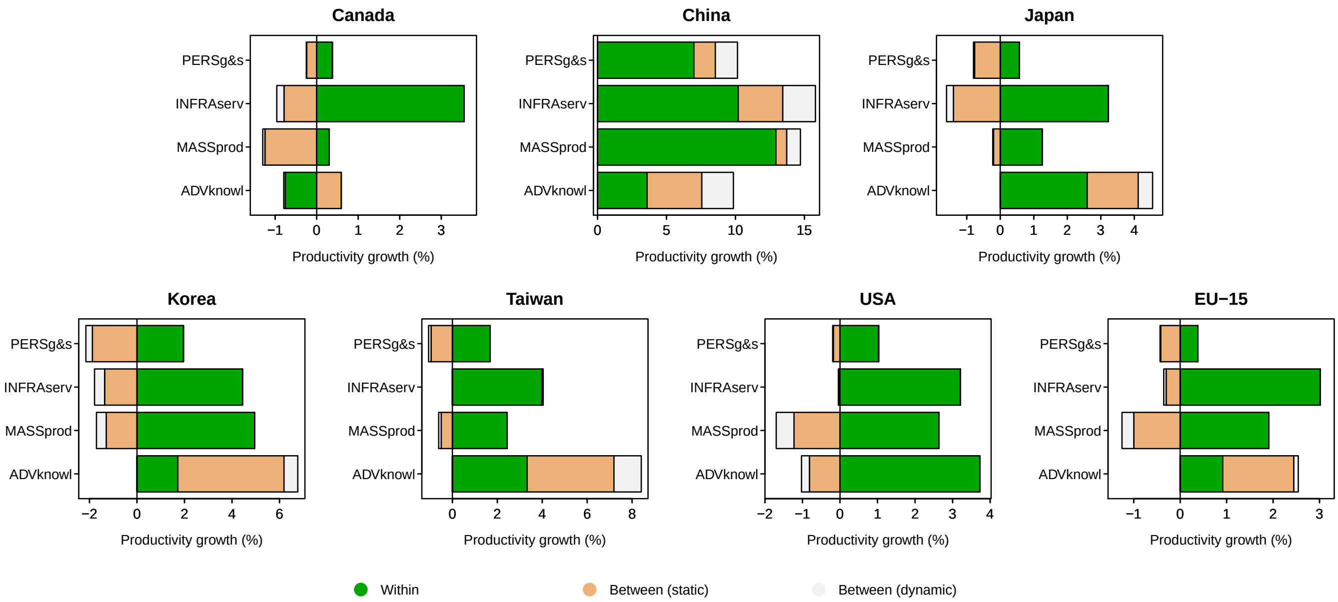

Figure 8: Productivity decomposition by sectoral innovation classes (2000-2007)

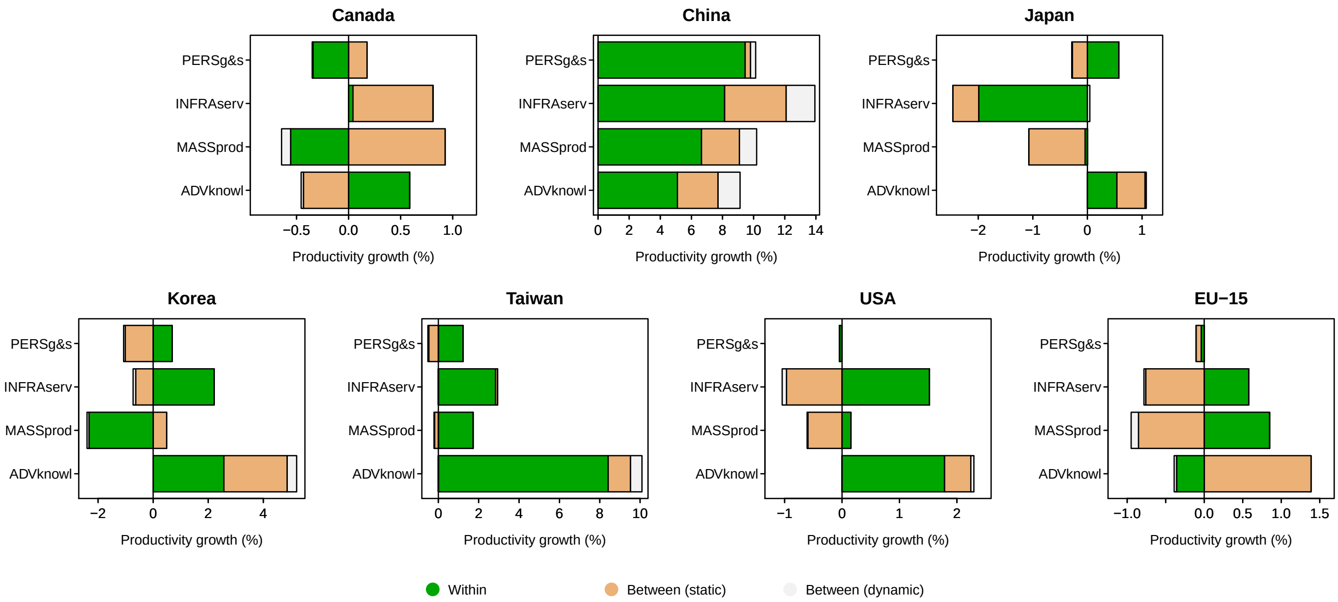

Figure 9: Productivity decomposition by sectoral innovation classes (2007-2014)

for various manufacturing sub-sectors.

Another significant stream of literature which is relevant for this discussion is the empirical mapping of the diversity of patterns of innovation at sectoral level carried out by scholars such as Pavitt, Malerba and Orsenigo since the mid 1980s. This literature has made a fundamental contribution in enhancing our understanding of the factors affecting sectoral patterns of innovative activities and also of the life-cycle of sectors.

In this perspective, an important direction for further research for the future will be that to connect this detailed understanding of innovation at sectoral level with the study of the contours of structural change and economic growth.

Acknowledgments

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Appendix A Data Sources

Historical sectoral shares: The dataset extends and updates the one by Herrendorf et al. (2014). The time span covered has been extended when possible using the most recent data sources and the group of countries considered now includes also: Argentina, Australia, Canada, Denmark, India, Italy, Norway and Taiwan. Data have been collected from various sources including: International historical statistics (Mitchell, 2013); GGDC Historical national accounts database (Smits et al., 2009); GGDC 10-Sector database (Timmer et al., 2015a); UNU MERIT structural change database (Szirmai and Foster-McGregor, 2017); EU and WORLD KLEMS (O'Mahony and Timmer, 2009); historical studies and national statistical offices data. Table 3 provides a detail of the sources used by country.

In Figure 2, due to data limitations, the first observations (before 1970) are constructed by aggregating cross-country data across various years. The periods considered are: 1856-65, 1866-78, 1879-88, 1889-99, 1900-09, 1910-19, 1920-29, 1930-39, 1940-49, 1950-59, 1960-69. The different country groups are:

- Group 1: Belgium, Denmark, Spain, France, Great Britain, Sweden, Usa. Period covered: 1856-2015.
- Group 2: Belgium, Denmark, Finland, Spain, France, Great Britain, Italy, Japan, Netherlands, Sweden, Usa. Period covered: 1878-2015.
- Group 3: Australia, Belgium, Canada, Denmark, Finland, Spain, France, Great Britain, Italy, Japan, Netherlands, Sweden, Usa. Period covered: 1900-2015.

Developing countries sectoral shares: GGDC 10-Sector database (Timmer et al., 2015a).

GDP per capita: the last release of the Maddison database (Bolt et al., 2018). The variable considered is the "cgdpcc" (GDP per capita in 2011 US $, multiple benchmarks).

Average years of schooling: the Barro-Lee historical dataset (Lee and Lee, 2016).

Life expectancy: the Clio-Infra project (Zijdeman and Ribeira da Silva, 2015)

Urbanization data: 1800-1949 Mitchell (2013); 1950-2015 UN World Urbanization prospects UNDESA (2018). Data from Mitchell (2013) include only cities with more than 200.000 inhabitants (or 500.000 in the associated urban agglomeration) in 1970. Some exceptions to this rule are made to account for cities of particular historical relevance. The UN prospects instead use country-specific definitions of urban areas. Hence, the former is much more conservative and leads to lower urbanization rates. To ensure consistency, the urbanization rate from Mitchell (2013) is re-scaled using the coefficient of the mean-shift dummy in the following regression.

$$URB_i = \alpha + \beta_1 t + \beta_2 DU + \beta_3 DT \tag{3}$$

Where URB_i are urbanization rates in country i before re-scaling; t is the time trend; DU is the mean-shift dummy which is 0 for $t < 1950$ and 1 otherwise; DT is a trend shift dummy which is 0 for $t < 1950 and (t - 1950)$ otherwise. Then urbanization rates figures from Mitchell (2013) are re-scaled adding the country-specific term β_2.

Sectoral shares and productivity (shift-share analysis): 1995-2015: EU KLEMS 2018 release (Jäger, 2017); countries included: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Italy, Netherlands, Portugal, Spain and United Kingdom. 2000-2007: the 2016 release of the WIOD Socio-Economic accounts (Timmer et al., 2015b); countries included: Canada, China, Japan, S. Korea, Taiwan, United States and EU-15. Labour productivity is obtained for each sectoral class dividing value added at constant prices (2010 = 100) by total employment.

Table A.1: Data sources by country and period

Country	Value Added (current prices)		Total Employment	
	Period	Sources	Period	Sources
Argentina	1900-2011	1900-1949: International Historical Statistics; 1950-2011: UNU-MERIT Strutural Change Database	1895-2011	1895-2011: International Historical Statistics; 1950-2011: GGDC 10-sector Database
Australia	1861-2009	1861-1952: International Historical Statistics; 1953-2009: UNU-MERIT Strutural Change Database	1901-2017	1901-1983: International Historical Statistics; 1984-2017: Australian Bureau of Statistics
Belgium	1835-2015	1835-1949: GGDC Historical National Accounts; 1950-1994: UNU-MERIT Strutural Change Database; 1995-2015: EU KLEMS	1846-2015	1846-1969: International Historical Statistics; 1970-2015: EU KLEMS
Canada	1926-2008	1926-1960: Historical Statistics (Statistics Canada); 1961-2008: Canada KLEMS;	1891-2010	1891-1960: International Historical Statistics; 1961-2010: Canada KLEMS
Denmark	1818-2015	1818-1969: Hansen (1983); 1970-1974: GGDC 10-sector database; 1975-2015: EU KLEMS	1850-2015	1850-1947: International Historical Statistics; 1948-1974: GGDC 10-sector database; 1975-2015: EU KLEMS
Spain	1850-2015	1850-1958: GGDC Historical National Accounts; 1959-1969: UNU-MERIT Strutural Change Database; 1970-2015: EU KLEMS	1860-2015	1860-1955: International Historical Statistics; 1956-1969: GGDC 10-sector database; 1970-2015: EU KLEMS
Finland	1860-2015	1860-1956: GGDC Historical National Accounts; 1957-1979: UNU-MERIT Strutural Change Database; 1980-2015: EU KLEMS	1805-2015	1805-1969: International Historical Statistics; 1970-2015: EU KLEMS
France	1827-2015	1827-1930: GGDC Historical National Accounts; 1945-1952: International Historical Statistics; 1953-1969: UNU-MERIT Strutural Change Database; 1970-2015: EU KLEMS	1856-2015	1856-1953: International Historical Statistics; 1954-1974: GGDC 10-sector database 1970-2015: EU KLEMS

(continued)

continued

Country	Value Added (current prices)		Total Employment	
	Period	Sources	Period	Sources
Great Britain	1801 - 2015	1801-1949: Bank of England historical dataset; 1950-1969: UNU MERIT Structural Change Database; 1970-2015: EU KLEMS;	1801-2015	1801-1947; Bank of England historical dataset; 1948-1969: GGDC 10-sector database; 1970-2015: EU KLEMS;
India	1900 - 2012	1900-1949: GGDC Historical National Accounts; 1950-2012: GGDC 10-sector database	1901-2010	1901-1959: International Historical Statistics; 1960-2010: GGDC 10-sector database
Italy	1861 - 2015	1861-1969: Bank of Italy National Accounts; 1970-2015: EU KLEMS	1871-2015	1871-1950; International Historical Statistics; 1951-1969: GGDC 10-sector database; 1970-2015: EU KLEMS
Japan	1885 - 2009	1885-1940: GGDC Historical National Accounts; 1950-1972: UNU MERIT Structural Change Database; 1973-2009: Japanese KLEMS; 2010-2011: GGDC 10-sector database	1872-2009	1872-1952; International Historical Statistics; 1953-1972: GGDC 10-sector database; 1973-2009: Japanese KLEMS; 2010-2011: GGDC 10-sector database
South Korea	1911 - 2011	1911-1952: GGDC Historical National Accounts; 1953-2011: GGDC 10-sector database	1955-2010	1955-1962; International Historical Statistics; 1963-2010: GGDC 10-sector database
Netherlands	1807 - 2015	1807-1937: GGDC Historical National Accounts; 1938-1949: International Historical Statistics; 1950-1969: UNU-MERIT Structural Change Database; 1970-2015: EU KLEMS	1955-2010	1807-1919: Smits et al. (2000); 1920-1958: International Historical Statistics; 1959-1969: UNU-MERIT Structural Change Database; 1970-2015 EU KLEMS
Norway	1830 - 2007	1830-1930: Grytten et al. (2015); 1931-1960: Statistic Norway (1965); 1961-1969: UNU-MERIT Structural Change Database; 1970:2017: Statistic Norway	1856-1990	1856-1961: International Historical Statistics; 1962-1988: Harildstad (1989); 1989-2017: Statistic Norway
Sweden	1800 - 2015	1800-2000: Krantz and Schön (2007); 2001-2015: EU KLEMS	1800-2015	1800-2000: Krantz and Schön (2007); 2001-2015: EU KLEMS

(continued)

continued

Country	Value Added (current prices)		Total Employment	
	Period	Sources	Period	Sources
Taiwan	1903 - 2012	1903-1950: GGDC Historical National Accounts; 1951-2012: GGDC 10-sector database	1905-2012	1856-1990: International Historical Statistics; 1991-2017: GGDC 10-sector database
United States	1800 - 2017	1800-1908: Gallman (1960); Gallman and Weiss (1969); 1909-1918: King (1930); 1919-1928: Kuznets (1947); 1929-1946: Carter et al. (2006); 1947-2017: Bureau of Economic Analysis	1840-2016	1840-1920: Carter et al. (2006); 1921-2016: Bureau of Economic Analysis

Appendix B Additional tables and plots

Dependent variable	Constant	Log GDP per cap.	(Log GDP per cap.)^2	Log Pop.	(Log Pop.)^2	Fix. Effects	$\mathbf{R^2}$	**N**
	Independent variables and controls							
AGRVA	4.02^{***}	-0.695^{***}	0.032^{***}	-0.032	0.001	*No*	0.848	525
	(0.206)	(0.047)	(0.003)	(0.024)	(0.001)			
AGRVA	3.504^{***}	-0.684^{***}	0.032^{***}	0.103^{***}	-0.008^{***}	*Yes*	0.931	525
	(0.193)	(0.036)	(0.002)	(0.029)	(0.001)			
MANVA	-3.34^{***}	0.712^{***}	-0.039^{***}	0.088^{***}	-0.004^{***}	*No*	0.428	525
	(0.198)	(0.045)	(0.003)	(0.023)	(0.001)			
MANVA	-3.461^{***}	0.757^{***}	-0.042^{***}	0.04	0	*Yes*	0.616	525
	(0.226)	(0.042)	(0.002)	(0.034)	(0.002)			
SERVA	0.341	-0.019	0.008^{***}	-0.058^{**}	0.003^{*}	*No*	0.766	525
	(0.219)	(0.05)	(0.003)	(0.025)	(0.001)			
SERVA	0.947^{***}	-0.068	0.01^{***}	-0.144^{***}	0.008^{***}	*Yes*	0.842	525
	(0.251)	(0.047)	(0.003)	(0.038)	(0.002)			
AGREMP	5.629^{***}	-0.879^{***}	0.038^{***}	-0.098^{***}	0.004^{**}	*No*	0.902	366
	(0.301)	(0.068)	(0.004)	(0.037)	(0.002)			
AGREMP	5.428^{***}	-0.791^{***}	0.034^{***}	-0.11^{**}	0.003	*Yes*	0.95	366
	(0.345)	(0.056)	(0.003)	(0.053)	(0.002)			
MANEMP	-4.587^{***}	1.062^{***}	-0.058^{***}	0.017	-0.001	*No*	0.576	366
	(0.238)	(0.054)	(0.003)	(0.029)	(0.001)			
MANEMP	-4.733^{***}	1.101^{***}	-0.06^{***}	-0.006	0.001	*Yes*	0.72	366
	(0.309)	(0.05)	(0.003)	(0.047)	(0.002)			
SERVEMP	-0.034	-0.184^{***}	0.02^{***}	0.08^{***}	-0.003^{*}	*No*	0.924	366
	(0.239)	(0.054)	(0.003)	(0.029)	(0.001)			
SERVEMP	0.309	-0.31^{***}	0.026^{***}	0.116^{**}	-0.003	*Yes*	0.948	366
	(0.317)	(0.051)	(0.003)	(0.048)	(0.002)			
SCHOOL	11.37^{**}	-3.977^{***}	0.394^{***}	-0.512	0.034	*No*	0.85	500
	(4.561)	(0.955)	(0.054)	(0.543)	(0.027)			
SCHOOL	-8.984^{**}	-1.815^{***}	0.23^{***}	0.298	0.095^{***}	*Yes*	0.952	500
	(3.968)	(0.665)	(0.036)	(0.555)	(0.028)			
LIFE EXPECTANCY	-29.349	19.068^{***}	-0.335	-11.024^{***}	0.561^{***}	*No*	0.79	498
	(23.917)	(5.315)	(0.299)	(2.825)	(0.141)			
LIFE EXPECTANCY	-140.676^{***}	30.281^{***}	-1.214^{***}	-9.108^{*}	1.207^{***}	*Yes*	0.902	498
	(24.415)	(4.228)	(0.233)	(3.858)	(0.193)			
URBANIZATION	-3.048^{***}	0.522^{***}	-0.022^{***}	0.17^{***}	-0.009^{***}	*No*	0.736	410
	(0.365)	(0.081)	(0.004)	(0.041)	(0.002)			
URBANIZATION	-0.724^{***}	0.136^{***}	-0.002	0.034	0.001	*Yes*	0.938	410
	(0.247)	(0.045)	(0.002)	(0.032)	(0.002)			

Notes: Standard errors in parenthesis. Significance levels: $^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.1$

Table B.1: Polynomial regression estimates with different dependent variables

Country	Period	Advanced knowledge providers			Mass production goods			Infrastructure services			Personal goods & services			Res.	Tot.
		With. (%)	Between (%)		With. (%)	Between (%)		With. (%)	Between (%)		With. (%)	Between (%)			
			Stat.	*Dyn.*		*Stat.*	*Dyn.*		*Stat.*	*Dyn.*		*Stat.*	*Dyn.*		
EU countries															
Austria	1995-2005	0.40	1.13	0.15	0.83	−0.09	−0.03	1.32	−0.16	−0.04	0.37	−0.08	−0.01	13.85	17.65
	2005-2015	0.21	0.73	0.04	0.13	−0.21	−0.01	0.25	−0.42	−0.02	0.14	−0.06	−0.00	0.89	1.67
Belgium	1995-2005	0.59	2.28	0.17	5.18	−1.64	−0.71	2.31	−0.79	−0.13	3.12	−1.51	−0.35	3.34	11.87
	2005-2015	−2.02	2.26	−0.47	5.84	−2.90	−1.28	0.80	−1.48	−0.08	−0.10	−1.20	0.01	0.55	−0.08
Denmark	1995-2005	0.00	0.96	0.00	−0.18	−0.55	0.03	1.95	−0.05	−0.02	0.04	−0.17	−0.00	12.82	14.83
	2005-2015	0.35	0.45	0.04	0.09	−0.20	−0.01	0.95	−0.11	−0.02	−0.10	0.02	−0.00	5.43	6.90
Finland	1995-2005	1.10	1.15	0.36	0.50	−0.02	−0.00	1.08	−0.14	−0.03	0.76	−0.31	−0.07	17.64	22.02
	2005-2015	−0.49	0.83	−0.08	−0.04	−0.26	0.01	0.43	−0.32	−0.03	−0.05	−0.30	0.00	−0.63	−0.93
France	1995-2005	0.10	0.89	0.02	0.64	−0.25	−0.10	1.05	0.15	0.03	0.28	−0.11	−0.01	10.47	13.16
	2005-2015	0.11	0.44	0.01	0.51	−0.41	−0.12	0.79	−0.29	−0.04	0.34	−0.00	−0.00	4.57	5.90
Germany	1995-2005	−0.25	1.50	−0.08	0.85	−0.33	−0.09	0.94	−0.24	−0.04	−0.24	−0.00	0.00	8.79	10.82
	2005-2015	−0.05	0.88	−0.01	0.68	−0.14	−0.03	0.47	−0.34	−0.03	0.03	−0.08	−0.00	4.45	5.83
Greece	1995-2005	−0.25	0.96	−0.11	0.07	−0.01	−0.00	3.61	0.02	0.02	0.28	−0.05	−0.00	24.60	29.15
	2005-2015	−0.88	0.46	−0.18	−0.05	−0.12	0.00	−0.65	−0.61	0.06	−1.19	0.23	−0.06	−8.99	−11.98
Italy	1995-2005	−0.62	1.51	−0.24	0.06	−0.19	−0.00	0.51	0.10	0.01	0.13	−0.44	−0.01	2.60	3.41
	2005-2015	−0.61	0.54	−0.08	0.18	−0.36	−0.03	0.19	−0.15	−0.00	−0.14	0.05	−0.00	−3.49	−3.90
Netherlands	1995-2005	1.01	0.45	0.10	0.62	−0.27	−0.11	2.17	0.01	0.00	0.32	−0.26	−0.03	12.13	16.14
	2005-2015	0.55	0.58	0.06	0.22	−0.23	−0.03	1.43	−0.56	−0.12	−0.17	0.04	−0.00	5.13	6.91
Portugal	1995-2005	−0.18	0.60	−0.04	0.68	−0.16	−0.08	1.87	0.16	0.07	0.69	−0.37	−0.05	12.23	15.42
	2005-2015	0.05	0.83	0.02	0.31	−0.13	−0.03	0.69	0.29	0.03	0.83	0.04	0.01	8.38	11.33
Spain	1995-2005	−0.53	1.10	−0.23	0.22	−0.26	−0.02	0.76	−0.31	−0.05	−0.69	−0.19	0.02	−0.61	−0.77
	2005-2015	0.19	0.81	0.05	1.09	−0.70	−0.32	1.07	0.10	0.02	−0.09	0.26	−0.00	10.18	12.65
U.K.	1995-2005	0.99	0.53	0.16	0.85	−0.57	−0.26	1.82	−0.06	−0.02	0.49	−0.15	−0.02	14.89	18.64
	2005-2015	0.63	0.72	0.11	0.23	−0.32	−0.05	0.38	−0.42	−0.03	0.23	−0.14	−0.01	2.26	3.59
EU-15	2000-2007	0.92	1.53	0.10	1.91	−1.00	−0.25	3.02	−0.30	−0.05	0.38	−0.42	−0.01	1.17	6.98
	2007-2014	−0.36	1.39	−0.03	0.85	−0.85	−0.10	0.58	−0.76	−0.02	−0.04	−0.07	0.00	0.61	1.20
Other countries															
Canada	2000-2007	−0.76	0.59	−0.04	0.30	−1.25	−0.05	3.55	−0.79	−0.17	0.38	−0.24	−0.01	1.86	3.37
	2007-2014	0.59	−0.43	−0.02	−0.56	0.93	−0.09	0.04	0.77	0.00	−0.34	0.18	−0.01	2.80	3.86
China	2000-2007	3.60	3.97	2.29	12.94	0.79	0.99	10.20	3.23	2.37	6.99	1.56	1.61	20.11	70.63
	2007-2014	5.10	2.61	1.41	6.65	2.44	1.11	8.14	3.95	1.85	9.46	0.35	0.33	15.31	58.70
Japan	2000-2007	2.60	1.52	0.43	1.25	−0.20	−0.02	3.23	−1.40	−0.21	0.57	−0.77	−0.03	2.11	9.08
	2007-2014	0.54	0.52	0.02	−0.04	−1.03	0.00	−1.99	−0.47	0.04	0.58	−0.27	−0.01	0.70	−1.42
Korea	2000-2007	1.72	4.47	0.58	4.96	−1.29	−0.41	4.44	−1.36	−0.43	1.96	−1.88	−0.27	4.02	16.50
	2007-2014	2.57	2.30	0.34	−2.33	0.49	−0.07	2.21	−0.63	−0.10	0.69	−1.01	−0.06	1.73	6.13
Taiwan	2000-2007	3.33	3.86	1.22	2.44	−0.50	−0.11	3.98	0.05	0.01	1.67	−0.95	−0.11	0.54	15.43
	2007-2014	8.42	1.11	0.57	1.73	−0.19	−0.03	2.83	0.10	0.01	1.22	−0.47	−0.05	1.43	16.68
USA	2000-2007	3.73	−0.81	−0.21	2.64	−1.23	−0.47	3.21	−0.04	−0.01	1.03	−0.18	−0.02	4.37	12.00
	2007-2014	1.79	0.46	0.05	0.15	−0.60	−0.01	1.52	−0.97	−0.08	−0.04	−0.01	0.00	3.54	5.81

Notes: Figures may not sum up to the total due to rounding.

Table B.2: Productivity decomposition by countries and sectoral innovation classes