Deindustrialisation reconsidered: Structural shifts and sectoral heterogeneity

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Deindustrialisation reconsidered: Structural shifts and sectoral heterogeneity

Fiona Tregenna[a] and Antonio Andreoni [a b]

Abstract

As a stylised fact of deindustrialisation, the relationship between Gross Domestic Product (GDP) and the share of manufacturing in GDP and employment generally follows an inverted-U pattern, across countries and over time. We analyse the changing dynamics of deindustrialisation, in particular premature deindustrialisation, and the heterogeneity of deindustrialisation experiences. Our results bring to light the high degree of heterogeneity within manufacturing, both between low-, medium- and high-tech manufacturing, and also within each of these categories. Significantly, not all sub-sectors of manufacturing display an inverted-U pattern. The greater the technological intensity of a manufacturing activity, the less concave is its pattern of development, becoming a monotonically increasing line and even a convex curve for the most high-tech sub-sectors. In terms of changes over time, while the curve shifts downwards and to the left for manufacturing as a whole, these dynamics also vary a lot by sub-sector. We provide an analytical framework for characterising the diversity of country experiences over time, and propose a working definition for premature deindustrialisation that allows us to identify possible premature deindustrialisers. The findings emphasise the importance of targeted policy responses that take into account the specific nature of deindustrialisation in particular country contexts, rather than 'one-size-fits-all' policies. For instance, it is clear that even high-income economies can grow the shares of at least some sub-sectors of manufacturing in GDP and/or employment.

Keywords: deindustrialisation, premature deindustrialisation, industrialisation, structural change, structural transformation, manufacturing, technological intensity

JEL codes: L16, L52, L60, O14, O25

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1. Introduction

Over the past two decades, the world economy has undergone profound structural transformations. Despite a number of catching-up economies having registered fast economic growth during this period, world industrial production has remained highly concentrated. Today, fewer than twenty countries control almost 90 percent of the world manufacturing value-addition activities. Many low- and middle-income countries are not part of this group of industrialised nations, and many of those countries that have managed to reach middle-income status have shown signs of premature deindustrialisation.

Premature deindustrialisation is a threat to low- and middle-income countries, as it shrinks their opportunities for technological development and their capacity to add value in global value chains and tradable sectors, thereby ultimately reducing their scope for cumulative increases in productivity. In order to reverse this trend, and to avoid falling behind in the global industrial landscape, appropriate packages of industrial, technological and innovation policies have to be deployed (Andreoni and Tregenna, 2020). These are essential economic policy tools for escaping the middle-income trap, increasing domestic value addition and reversing the processes of premature deindustrialisation.

The effectiveness of industrial policy in addressing premature deindustrialisation in low- and middle-income countries depends to a critical extent on the specific features of their own industrial system, their sectoral composition and structural trajectory, as well as the changing nature of premature deindustrialisation and the global distribution of industrial output. Indeed, countries that are traditionally classified in the group of middle-income countries are highly heterogeneous in terms of their sectoral composition, and thus also with respect to their experiences of deindustrialisation. Moreover, over the last three decades, countries have faced the increasing premature nature of deindustrialisation, and new crowding-out forces from fast-emerging industrialisers.

This paper presents a new empirical analysis of the dynamics of deindustrialisation across countries and across time, with a focus on the heterogeneity of deindustrialisation experiences and the changing global nature of premature deindustrialisation over the last three decades. We contribute to the literature in two main ways. Firstly, taking as a starting point the classical inverted-U pattern of industrialisation and deindustrialisation, we analyse the dynamics of manufacturing and identify the turning points of deindustrialisation at different points in time, as well as for manufacturing shares of both GDP and employment. We propose and operationalise a definition of premature deindustrialisation and identify possible premature deindustrialisers.

While analysis at the broad sectoral level remains important given the relevant common characteristics of manufacturing for development and growth, the increasing diversity within manufacturing points to the importance of drilling down to the sub-sectoral level. We thus disaggregate sub-sectors and categories of manufacturing and compare patterns of structural change. Our second, and most important, contribution thus lies in our analysis of the sub-sectoral heterogeneity in patterns of industrialisation and deindustrialisation. This is particularly important, both analytically and for policy, given the varying characteristics of sub-sectors within manufacturing, as well as the diverse patterns of performance across these sub-sectors.

The next section briefly reviews some of the salient literature. Section 3 describes our methodology and data. Section 4 presents and discusses the empirical analysis, and section 5 concludes.

2. Literature Review

A large and long-standing body of literature, associated in particular with the structuralist tradition in development economics and with the Kaldorian school of thought, has emphasised the importance of the manufacturing sector as an engine of economic growth, and of industrialisation as the key route to developing countries catching up with advanced economies.[1]

From these bodies of literature, the special characteristics associated with the manufacturing sector can be summarised as follows. First, there are strong intersectoral linkages, especially growth-pulling backward linkages. Second, there is superior scope for learning by doing, organisational innovation and development of collective capabilities. Third, there is scope for the promotion of technological progress, both through technological advances originating in the manufacturing sector and through enhancing technological progress in other sectors. Fourth, there are dynamic increasing returns to scale and greater scope for cumulative productivity increases than in other sectors. Fifth, there is the importance of the tradability of manufacturing for a country's balance of payments. Associated with this special role of manufacturing is the prominence accorded to structural change and to industrialisation as the pre-eminent pathway to sustained high rates of economic growth.

From this perspective, deindustrialisation is expected to negatively affect the possibility of sustained economic growth (see, for example, Palma, 2005, 2008). In particular, premature deindustrialisation is expected to negatively affect the prospects of developing countries achieving the structural transformation and sustained growth in productivity that are required for catching up with advanced economies (see, for example, Tregenna, 2016a, 2016b).

Here, we do not undertake a comprehensive review of the deindustrialisation literature.[2] Rather, we focus on two particular issues of direct relevance to our analysis: the stylised pattern of the

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[1] For seminal contributions from the structuralist tradition on the role of manufacturing and the importance of industrialisation, see, for instance, Chenery (1975); Chenery, Robinson, Syrquin and Feder (1986); ECLAC (1964, 1969); Furtado (1964); Hirschman (1958, 1971); Kuznets (1965); Prebisch (1950, 1963); Singer (1950); Sunkel, Maynard, Seers, and Olivera (1963) and Syrquin (1988). On the role of manufacturing from a Kaldorian perspective, see Kaldor (1966, 1978, 1980); and also Verdoorn (1949 [1993]); for discussions of Kaldor's work, see King (2009), Targetti (1992) and Thirlwall (1983, 1987). Examples of more recent applied work engaging with the role of manufacturing in the growth process and the importance of industrialisation include Alcorta, Haraguchi and Rezonja (2013); Andreoni and Chang (2016, 2017); Andreoni and Gregory (2013); Andreoni and Scazzieri (2014); Felipe, Mehta and Rhee (2019); Haraguchi and Rezonja (2013), Haraguchi, Cheng and Smeets (2017), Haraguchi, Martorano and Sanfilippo (2019); Lavopa and Szirmai (2016); Lee (2013); McMillan, Rodrik and Verduzco-Gallo (2014); Nübler (2014); Oqubay (2015); Szirmai (2012); Szirmai and Verspagen (2015); UNCTAD (2016); UNIDO (2018); and Wade (2012).

[2] Some recent studies of deindustrialisation include those by Andreoni and Tregenna (2018, 2021); Baldwin and Okubo (2019); Dasgupta and Singh (2006); Di Meglio, Gallego, Maroto and Savona (2018); Felipe and Mehta (2016); Kollmeyer (2018); Kucera and Milberg (2003); Nickell, Redding and Swaffield (2008); Palma (2005, 2008); Rodrik (2016); and Tregenna (2009, 2013a, 2015, 2016a, 2016b).

inverted-U curve of industrialisation and deindustrialisation, and sub-sectoral heterogeneity within manufacturing.

2.1 The inverted-U of deindustrialisation

Rowthorn's seminal contributions (1994, see also Rowthorn and Coutts (2004) and Rowthorn and Ramaswamy (1997)) established the now-familiar inverted-U curve of industrialisation and deindustrialisation. As countries' income per capita grows over time, industrialisation sees the share of manufacturing in total employment initially growing, and the share of agriculture declining concomitantly. At a turning point (which Rowthorn estimates to be around $12 000), the share of manufacturing in total employment levels off and declines. With deindustrialisation defined as a fall in the share of manufacturing in total employment, this turning point marks the onset of deindustrialisation.

Palma (2005, 2008) conceptualises deindustrialisation through the framework of Rowthorn's inverted-U curve. He starts with Rowthorn's conception of deindustrialisation through a transition into the downwards part of the curve, but identifies additional sources of deindustrialisation. First, he shows that the curve itself has shifted over time. This means that, whether or not countries reached the turning point, there was a declining level of manufacturing employment associated with each level of income per capita. This is represented by a series of downward shifts in the inverted-U curve over time. Second, he also shows that there was a decline in the level of income per capita at which the share of manufacturing in total employment begins to decline, in particular during the 1980s. This is understood as a leftwards shift in the turning point of the curve. Between 1980 and 1990, the income per capita turning point of the regression halved, from approximately $21 000 in 1980 to just over $10 000 in 1990 (1985 international US$). Together, these two phenomena mean that, since the 1960s, deindustrialisation has begun at lower levels of income per capita and at lower shares of manufacturing in total employment than previously was the case. Third, Palma defines the Dutch Disease as a specific form of deindustrialisation, resulting from the fact that commodity-rich countries have a lower path of industrialisation than commodity-poor ones. As some of the latter countries have become commodity rich, these countries have experienced an 'extra' degree of deindustrialisation. This is due to switching from one (higher) path of industrialisation to the other (lower) one. In this context, the Dutch Disease should only be regarded as the additional level of deindustrialisation associated with the latter movement.

Analysing the share of manufacturing in total employment for a sample of 103 countries for the year 2009, Tregenna (2015) finds a turning point of I$16 582 (2005 international dollars, PPP), corresponding to a share of manufacturing in total employment of 14 percent. Andreoni and Tregenna (2018, 2021) identify a turning point of approximately $17 000 (current 2015 US$), corresponding to a 12 percent employment share, for a sample of 148 countries and using data for the year 2015. Callaghan, Nell and Tregenna (2020) estimate an augmented specification including various determinants of the manufacturing share of GDP, using an instrumental variable (IV) approach, for a panel over the period 1970 to 2014. This yields a turning point of $36 102; without covariates and without instruments, the turning point is found to be $13 038, which is in a similar range to that found in comparable studies (both figures in constant 2010 US$).

Rodrik (2016) focused on deindustrialisation trends measured with different indicators and for different clusters of countries over recent decades. Among the main results, Rodrik shows that the inverted-U relationship between industrialisation (measured by employment or output shares) and incomes has shifted downwards. This suggests that deindustrialisation has kicked in earlier among late industrialisers, i.e. at much lower levels of income compared to early industrialisers. His results also show that, while Asian countries and those specialising in manufacturing exports have been less affected by premature deindustrialisation, Latin American countries have been strongly and negatively affected. Finally, by breaking down manufacturing employment by three skills levels (low skill, medium skill and high skill), Rodrik also shows that advanced economies have lost considerable employment (especially of the low-skill type), although they have retained significant shares of manufacturing output measured at constant prices. From a methodological point of view, Rodrik finally points out how different measures — i.e. manufacturing employment share, and manufacturing share of value added at both current and constant prices — yield different results in terms of the shape of the curve and its tipping point. In particular, nominal values tend to conflate movements in quantities and prices, thus the need for real value-based analyses.

Drawing in particular on Rodrik (2016), Haverkamp and Clara (2019) test the premature deindustrialisation hypothesis using a larger sample of countries. The aim is to provide policymakers with a practical tool to determine whether their country is indeed experiencing premature deindustrialisation. The paper advances a fourfold classification of different types of deindustrialisation constructed around two axes, one considering degrees of deindustrialisation and the other the extent to which deindustrialisation is 'premature' or 'legitimate'. The assessment is based on the inverted-U benchmarking exercise conducted at the manufacturing sector level.

Despite important developments in the literature, no study to our knowledge has attempted to disentangle patterns of deindustrialisation across manufacturing sub-sectors, at least not in the way that we undertake here. This is a critical limitation in the literature, as significant sub-sectoral heterogeneity is not captured by aggregating or effectively averaging sectoral trajectories across countries and across time. The aggregated inverted-U for overall manufacturing might obscure very different trajectories of industrialisation and deindustrialisation at the sub-sectoral level. For certain sub-sectors, deindustrialisation might not kick in at any levels of GDP per capita.[3]

2.2 Structural heterogeneity within manufacturing: sub-sectoral analysis

The structuralist and evolutionary literatures have acknowledged the importance of heterogeneity within manufacturing (and within other sectors) to varying degrees. The fact that, even within the manufacturing sector, sub-sectors are characterised by different technological degrees of intensity, different speeds in technological change, different levels of scale efficiency, different degrees of tradability, etc. has pushed several scholars to developing multi-sectoral models of

[3] This heterogeneity across sub-sectors is also further obfuscated by a less obvious type of heterogeneity within the same sub-sectoral category when considered over a long period of time. Intuitively, what we call 'wearing apparel' today, for example, is not the same sector that it used to be two or three decades ago. Cross-country regressions run over several decades for the entire manufacturing sector tend to miss this second type of heterogeneity.

economic growth and several types of sectoral classifications and taxonomies. Multi-sectoral models *a la* Pasinetti or Godwin have focused mainly on disproportional sectoral dynamics.

Among evolutionary scholars, Pavitt (1984) developed a seminal taxonomy aimed at analysing different sectoral patterns of technical change. This taxonomy is aimed at categorising industries and the firms therein by distinguishing four categories of industrial firms — i.e. supplier dominated, scale intensive, specialised suppliers and science based. Building on earlier work on industrial competitiveness and the OECD (1995)[4] work on technology intensity-based taxonomies, Lall (2001) also developed a taxonomy distinguishing groups of products that are generated in different sectors of the economy. These are resource-based manufactures, low-technology manufactures, medium-technology manufactures and high-technology manufactures.

Schumpeterian, neo-Schumpeterian and evolutionary perspectives draw attention to structural heterogeneity within manufacturing, particularly in relation to heterogenous behaviours across firms in the process of innovation and technological upgrading; see for instance Dosi, Pavitt and Soete (1990); Dosi, Malerba and Orsenigo (1994); Lee (2013); Nelson and Winter (1982); Rosenberg (1982); and Schumpeter (1942, 1947). Such approaches emphasise the centrality of technological and organisational innovation as drivers of structural transformation, and the importance of learning and of building different types of capabilities. There is, of course, considerable heterogeneity, both between and within sectors, in this regard.

This also links with the broader literature on technological upgrading, particularly within manufacturing. Innovation, the building of technological capabilities, and shifting to activities with higher technological content are part of the micro-foundations of structural transformation, and are crucial to developing countries catching up with advanced economies (see, for instance, Bell and Pavitt (1993), Fagerberg (2000), Figueiredo (2001), Hobday (2003, 2013), Lall (1996, 2001), Nübler (2014), Tassey (2007, 2010) and UNIDO (2016). 'Keeping pace' with innovation and technological progress is important for avoiding a 'middle-income technology trap' (Andreoni and Tregenna 2020). Given the high degree of heterogeneity in technological intensity within manufacturing, this also underscores the importance of sub-sectoral analysis, including by levels of technological intensity.

Andreoni and Chang (2017) have also pointed out how, in neo-classical economics, the only differences among production activities or sectors are due to different factor proportions that are used. However, they identify several other reasons why real-world production is characterised by 'structural heterogeneity' (see also Amsden (1991)). Different production activities exhibit very different internal dynamics and external impacts — in other words, there is heterogeneity across products and sectors. In fact, even within the same sector there are several products whose production requires the use of different technologies — process heterogeneity — and different organisational modes of production. Moreover, the boundaries of the sectors and their nature are constantly redefined by changes in technologies, organisations, products and markets. In particular, several scholars have pointed out how the manufacturing sector has been undergoing several genetic mutations driven by technological change (Andreoni and Chang 2016).

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[4] For a recent review of OECD technology classification, see Galindo-Rueda and Verger (2016).

As eloquently expressed by Tassey (2010:6):

> Most modern technologies are systems, which means interdependencies exist among a set of industries that contribute advanced materials, various components, subsystems, manufacturing systems and eventually service systems based on sets of manufactured hardware and software. The modern global economy is therefore constructed around supply chains, whose tiers (industries) interact in complex ways.

In a similar vein, Andreoni (2018) developed an industrial ecosystem model to study the relationships among sectoral value chains and underpinning technology platforms, which allows for the study of both specific sectoral features, as well as interstices among sectoral boundaries in the 'production space'. Sectoral interstices are places where diversification and innovation dynamics find particularly fertile ground, as increasingly noticeable in the new digital economy.[5]

Tregenna (2013b, 2014, 2015) draws attention to the heterogeneity within manufacturing, and has argued that — while there are important common denominators within manufacturing that have important implications for growth — there is also unevenness in the 'special characteristics' of manufacturing across its sub-sectors.

Cramer and Tregenna (2020) argue that, while sectoral categories remain relevant and manufacturing still has a special role to play, there are several ways in which the limitations of a sectoral classification have become increasingly apparent. There is growing heterogeneity of activities within sectors, categorical boundaries between sectors are increasingly 'fuzzy', and activities in different sectors are increasingly closely linked and integrated. For instance, 'servicification' brings growing integration and a blurring of boundaries between manufacturing and services. And with the 'industrialisation of freshness', not only are elements of manufacturing and agriculture increasingly integrated, but certain types of agricultural production have some of the 'special properties' traditionally associated with manufacturing in structuralist approaches.

Notwithstanding these various ways in which sectoral heterogeneity has been recognised, the literature on deindustrialisation has generally focused on aggregate sectors, and the shift away from manufacturing overall. This is based in the first instance on the structuralist view that manufacturing as a sector has important common denominators for growth and development, hence that it makes sense to analyse the sector as a whole. Furthermore, the very concept of structural change deals with the overall structure of the economy and hence focuses on shifts between broad sectors. Indeed, deindustrialisation as a concept is meaningful in terms of manufacturing as a whole. We cannot really speak of the relative decline in sub-sectors such as textiles or chemicals as 'deindustrialisation' in any meaningful sense.

Here, we build on the existing literature on the inverted-U of deindustrialisation, firstly analysing the overall dynamics of deindustrialisation and premature deindustrialisation in particular, and secondly focusing on dynamics at the sub-sectoral level.

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[5] See Andreoni and Gregory (2013) for a debate on the evolution of the pro-manufacturing versus pro-services debates, the problems associated with 'statistical illusions' and blurring sectoral interfaces; see also Tregenna (2010) for an empirical analysis of outsourcing from the manufacturing to services sector; see also Andreoni (2020).

3. Methodology

3.1 Empirical strategy

The first part of our analysis addresses the relationship between GDP per capita and the share of manufacturing in both total employment and GDP. First, we estimate the share of manufacturing employment in each of total employment and GDP as a function of GDP per capita and GDP per capita squared (in natural logs). The inclusion of the squared term takes account of the expected non-linear relationship between GDP per capita and the share of manufacturing. All analysis is conducted using simple OLS regressions, with robust standard errors.

Second, based on this simple regression analysis, we identify the level of GDP per capita and share of manufacturing in both total employment and GDP that are associated with the 'turning points', at which the share of manufacturing in employment and GDP levels off and begins to decline. Third, we characterise country trajectories based on countries' changes in share of manufacturing in total employment and GDP, and on whether their actual shares of manufacturing in total employment and GDP are higher or lower than the cross-country econometric analysis would predict. Fourth, we categorise countries based on these two dimensions. Finally, combining this with data on countries' 2015 level of GDP per capita and manufacturing employment share, allows us to identify possible premature deindustrialisers.

For our analysis at the sub-sectoral level, we disaggregate manufacturing firstly into three categories by level of technological intensity (low-, medium- and high-tech). Next, we disaggregate by specific manufacturing sub-sectors of interest. In each case, we estimate the relationships between GDP per capita (and its square) and the share of the disaggregated manufacturing category in both total employment and GDP. We also consider shifts in the curves over time. This part of the analysis is intended to shed light on the diverse sub-sectoral patterns within manufacturing.

3.2 Data

Moving from a broad discussion of dependent contract status, this paper puts forward a simple framework for situating workers' relationships a firm and establishing firm obligations. The greater the degree of worker dependence on the firm and/or the firm's control over the work, the greater the positive obligation of the firm to provide the protections and benefits associated with a standard employment relationship. This framework (Figure I) modifies that put forward by Kuhn and Maleki (2017, 102) for classifying gig work, and, in the context of this article, is explicitly interested in linking degrees of control and dependence to firm responsibility.

For the overall manufacturing analysis, data on manufacturing share of GDP, GDP and population is from the United Nations (UN) Main National Accounts database (UNMNA). Data on manufacturing share of employment is taken from the International Labour Organization (ILO) ILOSTAT database. The sample comprises 161 countries, with excellent coverage across regions and across levels of development. For purposes of comparability, the country sample is kept consistent between years and for the analysis of both employment shares and GDP shares.

For the sub-sectoral analysis, we utilise sub-sectoral employment and value-added data from a rich database provided on request by UNIDO. This is based on the UNIDO INDSTAT2 database, but has been constructed in order to maximise consistency across countries, over time and between variables (Pahl, n.d.). This is supplemented with data on GDP per capita (which we calculate from series on GDP in constant 2005 US$ and population, both obtained from the United Nations Main National Accounts database). Total employment data is taken from the ILO Key Indicators of the Labour Market.

The dataset for the sub-sectoral analysis spans the period 1990 to 2014, but is unbalanced, as the maximum coverage of 78 countries is included only for the years 1998 to 2008. Country coverage is incomplete in the early years and unfortunately tails off sharply over the period 2009 to 2014, with only 25 countries covered in 2014. We use the 18-year period from 1993 to 2010 for our sub-sectoral analysis, which balances country coverage — specifically the inclusion of major economies — with maximising the time period included in the analysis. This yields a final sample of 67 countries for which complete data is available for the period 1993 to 2010, which we use for this part of the analysis. It is hoped that, if more recent data becomes available, this part of the analysis can be updated in the future.

Our sample includes 28 countries from East Asia and the Pacific, 48 from Europe and Central Asia, 30 from Latin America and the Caribbean, 21 from the Middle-East and North Africa, two from North America, eight from South Asia and 45 from sub-Saharan Africa. There are 55 high-income, 54 upper-middle-income, 43 lower-middle-income and 30 low-income countries. In terms of levels of industrial development (UNIDO classification), there are 44 industrialised economies, 32 emerging industrial economies, 64 other developing economies and 41 least-developed countries. Table A1 in the Appendix lists all countries included in the analysis and indicates their classification by region, income group and level of industrial development. The countries in our overall manufacturing sample, and in the more restricted sample for the sub-sectoral analysis, account for 99 percent and 83 percent respectively of current world GDP, so can be considered representative of global patterns.

Manufacturing is disaggregated into 17 sub-sectors (some of these are combined from the 23 more disaggregated sub-sectors in the INDSTAT2 data). Table 1 shows these sub-sectors, grouped according to level of technology as per the UNIDO classification.[6]

[6] For a discussion of the UNIDO classification, also in relation to the OECD R&D-based expenditure classification, see: https://stat.unido.org/content/focus/classification-of-manufacturing-sectors-by-technological-intensity-%2528isic-revision-4%2529;jsessionid=4DB1A3A5812144CACC956F4B8137C1CF

Table 1: Sub-sectoral groupings and their technological classification

Low-tech	**Medium-tech**	**High-tech**
Food and beverages (15) and Tobacco products (16)	Coke, refined petroleum products, nuclear fuel (23)	Chemicals and chemical products (24)
Textiles (17)	Rubber and plastics products (25)	Machinery and equipment n.e.c. (29) and Office, accounting and computing machinery (30)
Wearing apparel, fur (18) and Leather, leather products and footwear (19)	Non-metallic mineral products (26)	Electrical machinery and apparatus (31) and Radio, television and communication equipment (32)
Wood products (excl. furniture) (20)	Basic metals (27)	Medical, precision and optical instruments (33)
Paper and paper products (21)	Fabricated metal products (28)	Motor vehicles, trailers, semi-trailers (34) and Other transport equipment (35)
Printing and publishing (22)		
Furniture; manufacturing n.e.c. (36) and Recycling (37)		

4. Empirical Analysis

4.1 Descriptive statistics

Table 2 summarises descriptive statistics for the key variables used in our analysis (statistics for individual sub-sectors not shown for reasons of brevity). While manufacturing as a whole, as well as the three categories thereof (for a smaller country sample), all fell as a share of both GDP and employment, these decreases were relatively small over these periods. The largest declines can be observed for the shares of low-tech manufacturing.

Table 2: Summary statistics

	Year	Obs.	Mean	Std. dev.	Min.	Max.
Aggregate analysis						
GDP per capita	2005	181	10 074.77	15 161.47	150.49	81 570.64
	2015	181	13 174.58	18 281.59	95.79	101 959.30
Manufacturing share of employment	2005	181	11.51	6.07	0.40	29.40
	2015	181	10.55	5.39	0.20	27.30
Manufacturing share of GDP	2005	181	13.96	7.27	0.60	42.50
	2015	181	13.01	7.35	0.50	48.10
Sub-sectoral analysis						
GDP per capita	1993	67	12 999.36	13 951.99	156.42	65 024.73
	2010	67	18 954.91	18 565.63	300.01	87 830.88
Low-tech share of employment	1993	67	6.51	5.02	0.33	28.45
	2010	67	4.51	2.67	0.32	12.99
Low-tech share of GDP	1993	67	7.90	4.70	1.59	24.89
	2010	67	4.29	2.16	0.60	12.65
Medium-tech share of employment	1993	67	2.60	1.79	0.04	7.99
	2010	67	2.29	1.44	0.05	6.17
Medium-tech share of GDP	1993	67	4.71	3.07	0.42	12.72
	2010	67	3.34	1.98	0.01	13.38
High-tech share of employment	1993	67	3.93	3.22	0.01	13.51
	2010	67	3.09	2.72	0.03	12.56
High-tech share of GDP	1993	67	5.64	4.35	0.25	19.35
	2010	67	4.39	3.84	0.01	18.32

4.2 The inverted-U of industrialisation and deindustrialisation

The regressions for manufacturing as a share of both employment and GDP give the expected coefficients and are highly statistically significant, yielding the inverted-U curves shown in Figure 1. The associated turning points — the level of GDP per capita and associated share of manufacturing in total employment and GDP at which the manufacturing share levels off and begins to decline — are reported in Table 1. These turning points are in a similar range to those found in the existing literature.

The vertical drop in the curve, corresponding to the fall in the shares of manufacturing in both employment and GDP at the turning point, as seen in Table 1, indicates that deindustrialisation is setting in at lower levels of industrialisation than was previously the case. One surprising observation is the rightwards shift of the employment curve, as the expectation was for deindustrialisation to set in at progressively lower levels of income per capita.[7]

[7] Similarly, Palma (2008) finds that, while the turning point of deindustrialisation occurred at falling levels of GDP per capita over time in earlier periods, this was reversed over the period 1990 to 2000 (the most recent in his analysis). He attributes this to the fact that deindustrialisation affected mainly advanced economies during the 1980s, but primarily middle-income, developing countries during the 1990s.

The fact that the employment turning points are lower than those for GDP is indicative of productivity in manufacturing being higher than in other sectors.

Figure 1: Estimated relationship between GDP per capita and manufacturing share

Figure 1a: Manufacturing share of total employment

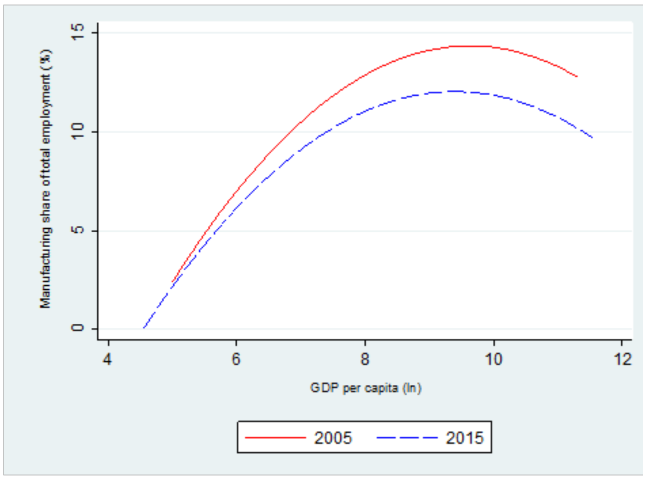


Figure 1b: Manufacturing share of GDP

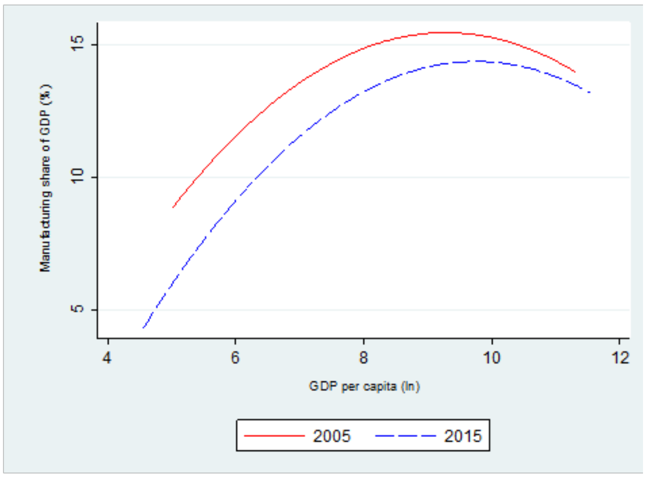


Table 3: Turning points of manufacturing regressions

		Turning point	
		Manufacturing share (%)	GDP per capita ($)
Manufacturing share of GDP	2005	15.5	10 797.8
	2015	14.4	17 310.8
Manufacturing share of employment	2005	14.3	15 217.6
	2015	12.0	12 119.0

Next, we categorise countries based on two dimensions. Firstly, whether their actual share of manufacturing in each of total employment and GDP in 2015 was higher or lower than would be 'predicted' based on their level of GDP per capita in 2015, and the estimated coefficients from the regression (that is, the sign of the residual term for each country). This dimension gives a sense of which countries may be 'under-industrialised' given their level of GDP per capita. Where this is positive, a country falls above the relevant curve in Figure 1, and conversely where this is negative. Secondly, whether they experienced an increase or decrease in the share of manufacturing in their total employment, or alternatively GDP, between 2005 and 2015. This second dimension indicates which countries can be considered (simply on the basis of sectoral shares) to have deindustrialised during this period.

Taken together, these two dimensions allow us to group countries into four broad categories, depicted schematically in the four quadrants of Figure 2. As in a bicycle race, we identify two main groups of countries, a group of countries (cyclists) that are *ahead* and a group that is left *behind*.

Within each of these two groups, however, not all cyclists are advancing at the same speed. Therefore, we further distinguish those countries that are *slowing* from those that are *speeding*.

Quadrant I includes countries that are *ahead and speeding*, in which the share of manufacturing in employment or GDP is higher than expected in 2015, and in which this share has grown between 2005 and 2015. Based on this analysis, these countries do not raise a concern in terms of deindustrialisation. This quadrant includes developing Asian countries such as Vietnam, Indonesia, Myanmar, India, Bangladesh and Pakistan. Countries in Quadrant IV are also growing their share of manufacturing in total employment or GDP, which in 2015 remains below their 'expected' values. Thus, even though these countries might be regarded as 'under-industrialised', they show evidence of industrialising during this decade — they are *behind but speeding*.

Countries falling in quadrants II and III can be characterised as possible deindustrialisers in that their share of manufacturing in total employment (Figure 3a) or GDP (Figure 3b) fell between 2005 and 2015. Yet, in the case of Quadrant II countries, their manufacturing employment share in 2015 still remains above their 'expected' level. These are countries *ahead but slowing*, with many European countries (denoted in blue) located here.

In Quadrant III we find countries that are *behind and slowing* — the worst place for a country to find itself in from the standpoint of industrialisation and structural transformation. For the case of manufacturing shares of total employment (Figure 3a), here we find countries such as Zimbabwe, South Africa, Chile, the Philippines and the United Kingdom.

Figure 2: Characterisation of deindustrialisation patterns

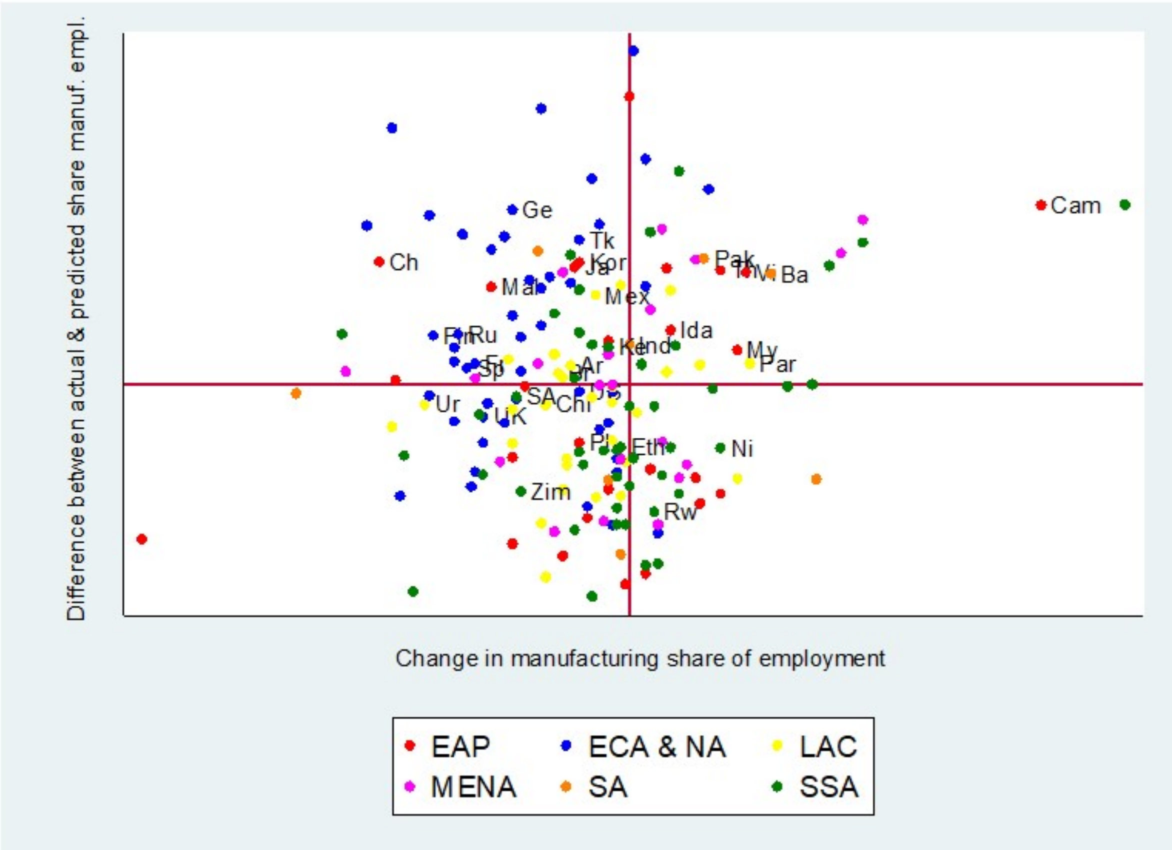
y-axis: difference between actual and predicted share of manufacturing

QUADRANT II: Ahead but slowing Manufacturing share decreased (2005-2015) and Manufacturing share higher than predicted (2015)	**QUADRANT I: Ahead and speeding** Manufacturing share increased (2005-2015) and Manufacturing share higher than predicted (2015)
x-axis: change in manufacturing share, 2005-2015	
QUADRANT III: Behind and slowing Manufacturing share decreased (2005-2015) and Manufacturing share lower than predicted (2015)	**QUADRANT IV: Behind but speeding** Manufacturing share increased (2005-2015) and Manufacturing share lower than predicted (2015)

From the standpoint of structural change and concerns around the impact of deindustrialisation on growth, it is the countries falling in Quadrant III that potentially raise more significant concerns. In these countries, the share of manufacturing in employment is lower than would be expected, and they have been further deindustrialising over the past decade. Rather than catching up to their 'expected' level of industrialisation, this group of countries has been falling further behind. Furthermore, some of these countries had a higher than expected level of industrialisation in 2005, but fell below the curve by 2015.

The distribution of country points between the four quadrants is shown in Figures 3a and 3b.

Figure 3a: Scatterplot of country results: employment

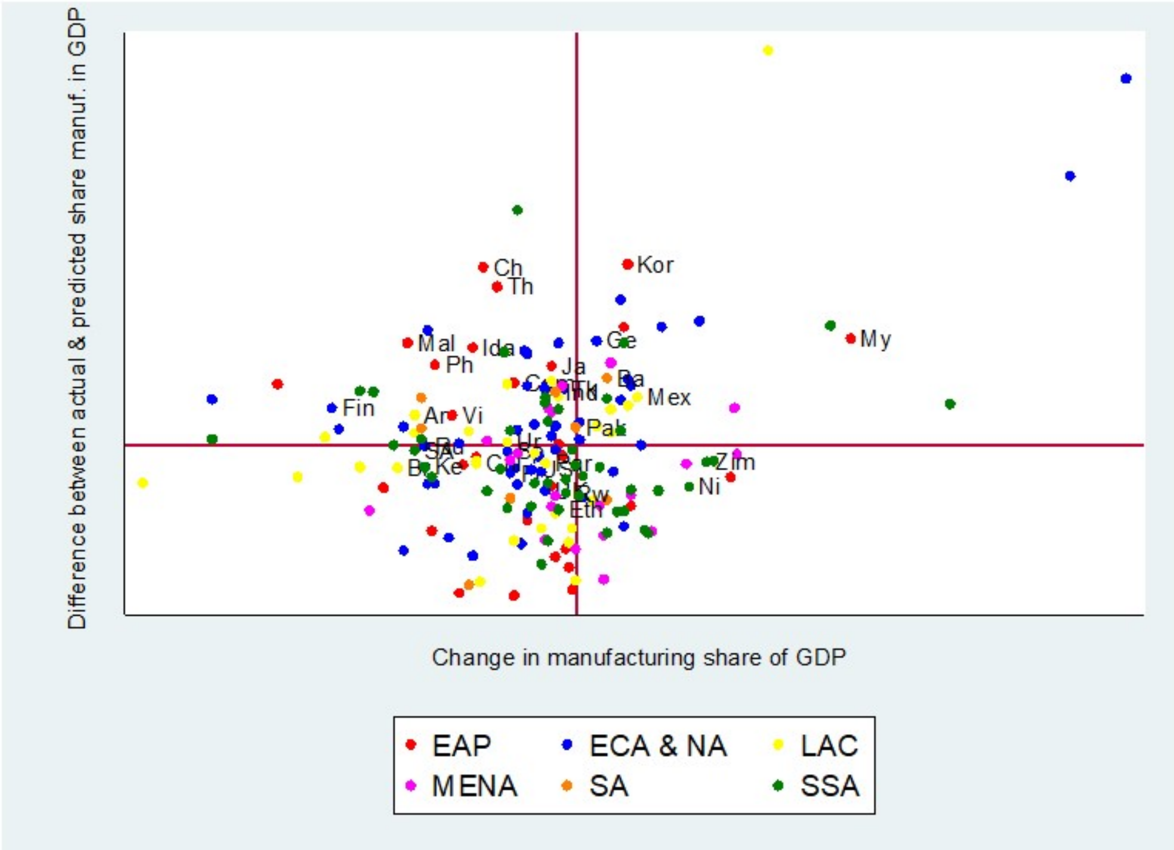


Notes: Ar = Argentina; Ba = Bangladesh; Br = Brazil; Cam = Cambodia; Chl = Chile; Ch = China; Eth = Ethiopia; Fin = Finland; Fr = France; Ge = Germany; Ind = India; Ida = Indonesia; Ja = Japan; Ke = Kenya; Kor = Korea (Republic of); Mal = Malaysia; Mex = Mexico; My = Myanmar; Ni = Nigeria; Pak = Pakistan; Par = Paraguay; Ph = Philippines; Ru = Russia; Rw = Rwanda; SA = South Africa; Sp = Spain; Th = Thailand; Tk = Turkey; UK = United Kingdom; US = United States; Ur = Uruguay; Vi = Vietnam; Zim = Zimbabwe.

Colour-coded regional groups: EAP = East Asia and Pacific; ECA & NA = Europe and Central Asia, and North America; LAC = Latin America and the Caribbean; MENA = Middle East and North Africa; SA = South Asia; SSA = sub-Saharan Africa.

Each point in this scatterplot indicates a country's change in the share of manufacturing in total employment (x-intercept) and difference between actual and predicted share of manufacturing in its total employment (y-intercept). Quadrants as in Figure 2.

Figure 3b: Scatterplot of country results: GDP



Notes: Country key and regional groups as in Figure 3a.

Each point in this scatterplot indicates a country's change in the share of manufacturing in GDP (x-intercept) and difference between actual and predicted share of manufacturing in GDP (y-intercept). Quadrants as in Figure 2.

Next, we further divide Quadrant III countries into those that might be regarded as possible premature deindustrialisers. We propose a working definition for identifying premature deindustrialisation as countries in which all four of the following conditions hold (set out here for the period 2005 to 2015):

(1) the share of manufacturing in total employment or GDP fell between 2005 and 2015 (indicative of deindustrialisation in general);

(2) the share of manufacturing in total employment or GDP in 2015 was less than would be expected based on their GDP per capita (i.e. they fell below the curve); and

(3) their GDP per capita in 2015 was below the level of GDP per capita associated with the turning point in the relationship based on the pattern found across countries (i.e. they fell to the left of the turning point of the curve). This condition excludes countries in Quadrant III with levels of GDP per capita above the income turning point (i.e. advanced economies that are deindustrialising).

These ‘possible premature deindustrialisers’ are listed in Table 4, separately for shares of GDP and of total employment. It is important to note that this identification is suggestive rather than definitive for individual countries. A country being classified here as a ‘possible premature deindustrialiser’ does not necessarily confirm that it is indeed experiencing premature deindustrialisation; similarly, a country may actually be experiencing premature deindustrialisation despite not being classified here as a ‘possible premature deindustrialiser’. Twenty-one countries meet the indicative criteria for both employment and GDP shares (i.e. appearing in both columns of Table 4).

Table 4: Possible premature deindustrialisers

By share of GDP	By share of employment
	Afghanistan
	Albania
	Angola
Armenia	Armenia
Azerbaijan	
Barbados	
Belize	Belize
Bolivia	Bolivia
	Botswana
Brazil	
Burkina Faso	
	Burundi
	Cameroon
	Cape Verde
Chile	
Colombia	
Costa Rica	Costa Rica
	Cuba
	Dominican Republic
	Ecuador
Eritrea	Eritrea
Ethiopia	Ethiopia
Fiji	Fiji
Gambia	
Georgia	Georgia
	Ghana
Guyana	Guyana
Haiti	
Iran	
	Iraq
	Jamaica
Kazakhstan	Kazakhstan
Kenya	
	Kyrgyzstan
Lao	
Latvia	
Libya	
Madagascar	

By share of GDP	By share of employment
Maldives	Maldives
	Mali
	Mauritania
	Moldova
Montenegro	Montenegro
Mozambique	Mozambique
Namibia	Namibia
Nepal	Nepal
Palestine	
Panama	
Papua New Guinea	
Paraguay	
	Peru
	Philippines
Russian Federation	
Rwanda	
Saint Lucia	Saint Lucia
Saint Vincent and the Grenadines	Saint Vincent and the Grenadines
Samoa	Samoa
	Sao Tome and Principe
Sierra Leone	Sierra Leone
South Africa	South Africa
Suriname	Suriname
	Tajikistan
Tanzania	Tanzania
Timor-Leste	
Togo	
Tonga	
Uganda	
Vanuatu	Vanuatu
Zambia	
	Zimbabwe

4.3 Sub-sectoral analysis

In the second part of our empirical analysis, we drill down beyond overall manufacturing to analyse the dynamics of industrialisation and deindustrialisation at the sub-sectoral level. The degree of technological intensity varies considerably across sub-sectors of manufacturing in terms of the types and amount of production, technological and organisational capabilities that are required to produce at an efficient scale, with innovative products, and to compete in exporting. This implies that the industrialisation and deindustrialisation trajectories of these sub-sectors are likely to differ. This would reflect the fact that a country would be able to enter and be competitive in each sub-sector at different levels of economic development (measured by GDP per capita). Entering here means that the country becomes able to employ a larger number of people and produce a relatively increasing share of value addition in GDP. The idea that the industrialisation trajectory of a given sub-sector reaches a turning point is based on an idea of structural change *between* sectors (and the increasing shift from manufacturing to services), and *within* manufacturing sub-sectors, from low- to high-tech sub-sectors. While the between-sectors trajectory has been discussed widely (see above), we do not know the extent to which within-manufacturing sub-sector countries move from low- to medium- and high-tech sub-sectors and eventually exit even from the latter, to become completely service-led economies.

Figure 4 compares the patterns for the three broad sectors of manufacturing by tech level, for both shares of employment and GDP, at two points in time (1993 and 2010). Figure 5 shows similar trends, but with an emphasis on how the patterns have shifted over time for each category.

Our first observation is how varied the trends are for the three tech categories of manufacturing. A clear inverted-U with a pronounced hump is evident for low-tech manufacturing. This shape reflects the overall manufacturing trajectory discussed above in terms of tipping point, although the shape of the curve varies by measure (share of GDP or employment) and over time.

In contrast, a striking result is the fact that high-tech manufacturing is monotonically increasing in its shares of both employment and GDP, and is barely concave. This suggests that, at increasing level of economic development (measured by GDP per capita), the cross-countries benchmark trajectory is one of continuous industrialisation. Although this analysis is across countries, the pattern may suggest that, once a country has entered a certain high-tech manufacturing sub-sector, it can increasingly (and relatively) employ more people in this sub-sector group, and that the latter will keep increasing its relative share of contribution to GDP. This result challenges the idea that the normal trajectory for countries reaching a high level of GDP is one of deindustrialisation, with a shift from manufacturing to services.

Figure 4: Patterns by tech category

Figure 4a: Share of total employment, 1993

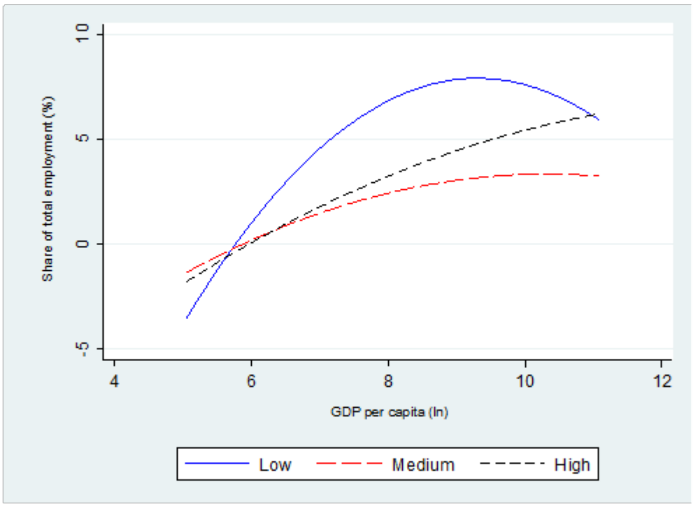


Figure 4b: Share of GDP, 1993

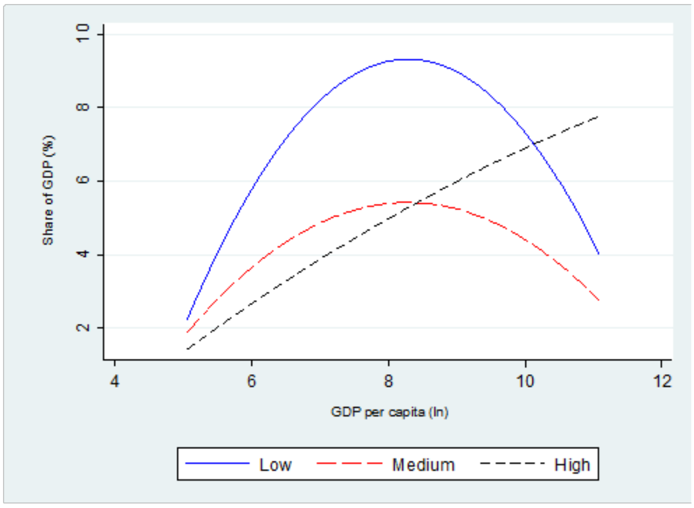


Figure 4c: Share of total employment, 2010

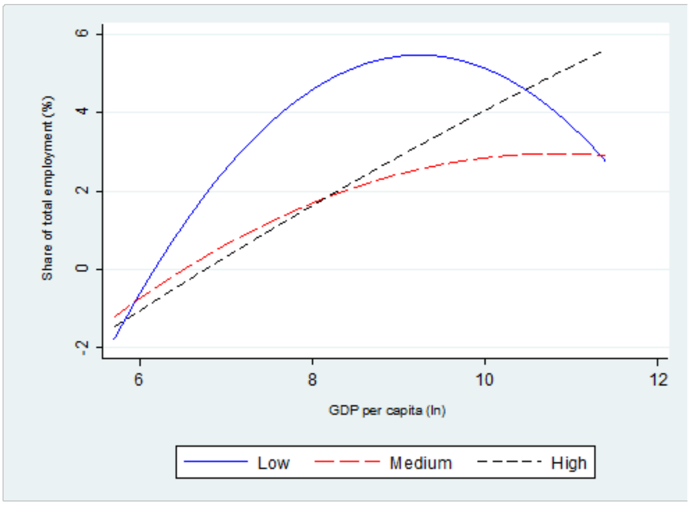
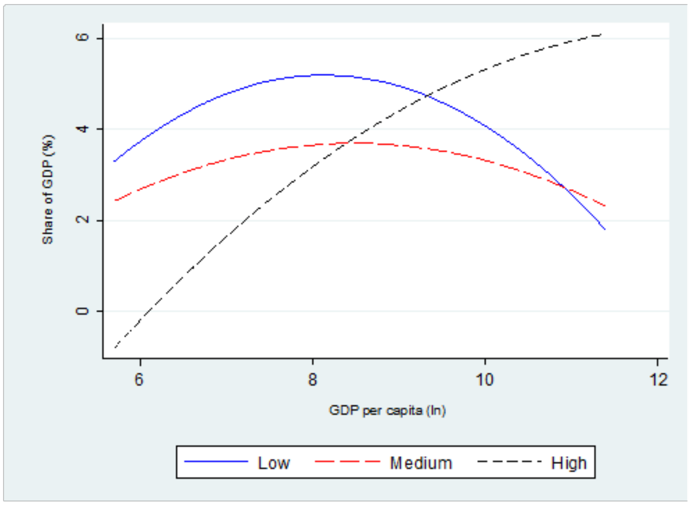


Figure 4d: Share of GDP, 2010



We also find that, even for the medium-tech group of manufacturing sub-sectors, the curve does not turn down dramatically; instead, it merely levels off in the case of share of employment (Figure 4c). This means that, while the initial acceleration in medium-tech sub-sectors of manufacturing will slow down after a certain level of GDP per capita, the share typically remains fairly steady thereafter. However, when estimated as a share of GDP, the fact that the medium-tech manufacturing sub-sector curve tends to follow an inverted-U curve, albeit a relatively flat one, shows that the relative contribution of this group of sub-sectors to GDP decreases in these countries. These results might be due to two different, complementary dynamics.

On the one hand, many medium-tech manufacturing sub-sectors (as defined in the UNIDO classification) are based on the mass production of goods that are traded almost as commodities in the international market. These are often industrial raw materials or components of other medium-high-tech products, such as fabricated metals, or large consumption products whose prices tend to decline very fast as a result of global competition and efficient scale production.

On the other hand, there is a more domestic dynamic explaining the shape of the curve for the medium-tech sub-sectors of manufacturing. While retaining employment and shares of GDP from medium-tech sectors, the more countries advance in their development, the more high-tech sectors and specific types of services (e.g. production-related and business services)[8] become their drivers of wealth generation. This is why relatively medium-high-tech sub-sectors of manufacturing slow down (and eventually shrink) in terms of their contribution to GDP.

Based on this first set of disaggregated estimates for three groups of manufacturing sub-sectors, we can now move to the study of each of them over time and for the two different measures of industrialisation and deindustrialisation — i.e. shares of employment and shares of GDP. Figure 5 shows the shifts over time for three datapoints: 1993, 2001 and 2010. These three points have been carefully chosen, as they reflect a different configuration in the global manufacturing landscape, as well as maximising both country and time coverage, as discussed earlier. The 1993 datapoint allows us to look at the curves in a pre-global China (China joined the WTO in 2001). The mid-way 2001 datapoint allows us to look at the global manufacturing landscape including China (China started picking up in terms of its world manufacturing value-added shares starting from 1995, gaining roughly 4.5 percent in its share every five years since then). The last datapoint, 2010, captures the post-financial crisis scenario. This factors in the dramatic manufacturing loss among developed countries associated with the financial crisis, and the resulting disproportional redistribution of manufacturing value added.[9]

Estimated curves for the low-tech group of manufacturing sub-sectors show a consistent trend since 1993. The tipping point in both employment and value-added shares to GDP shifts continuously downwards, especially dramatically when measured in share of GDP. In the case of the medium-tech group of manufacturing sub-sectors, the tipping point has also shifted downwards, but with some changes in shape. The China crowding-out effect is likely to be especially relevant for this segment of manufacturing. Finally, high-tech sub-sectors of manufacturing seem to retain the same trajectory, although it has shifted slightly down, perhaps reflecting the general trend of a shift to services in many countries. Fast catching-up industrialisers like China and Malaysia, and transition economies like Poland, have entered a number of high-tech sectors, also as a result of outsourcing and new global value chain structures.

[8] As discussed in Andreoni and Gregory (2013), the relatively increasing contribution of services in the most advanced economies is the result of a statistical illusion associated with another type of heterogeneity within services. It is driven by certain types of production-related services that used to be part of manufacturing and increasingly have been outsourced, although retaining typical features of manufacturing processes.

[9] See Andreoni and Upadhyaya (2014).

Figure 5: Shifts over time, by tech category

Figure 5a: Share of low-tech manufacturing in total employment, 1993-2001-2010

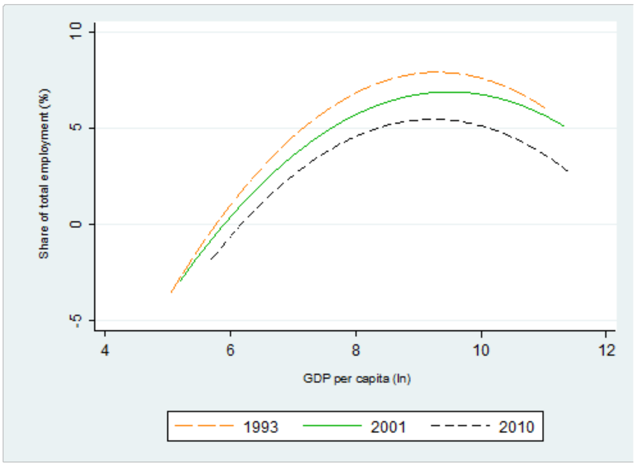


Figure 5b: Share of low-tech manufacturing in GDP, 1993-2001-2010

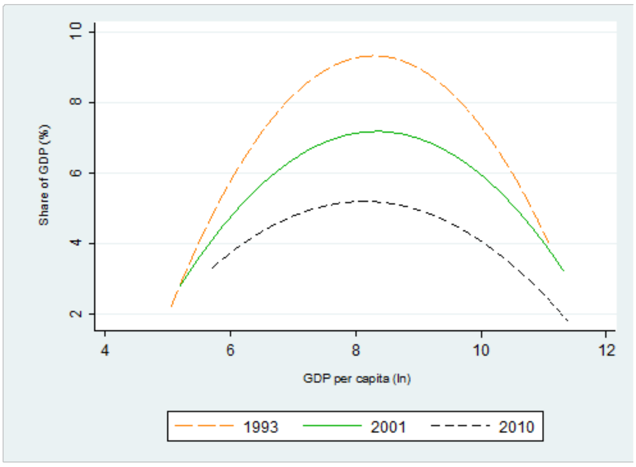


Figure 5c: Share of medium-tech manufacturing in total employment, 1993-2001-2010

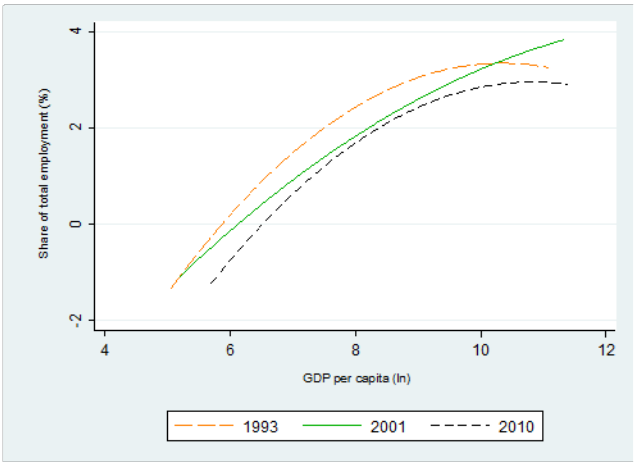


Figure 5d: Share of medium-tech manufacturing in GDP, 1993-2001-2010

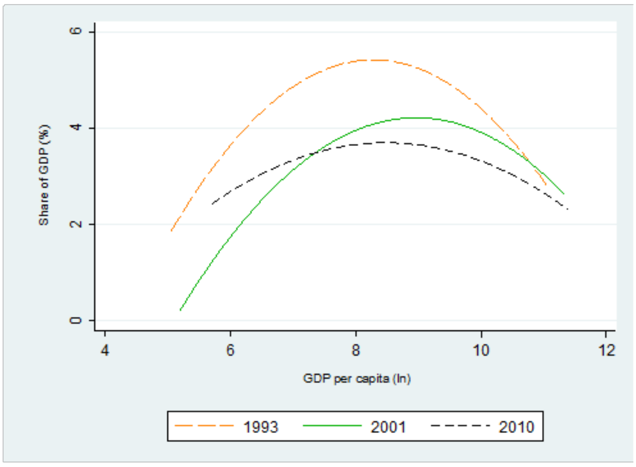


Figure 5e: Share of high-tech manufacturing in total employment, 1993-2001-2010

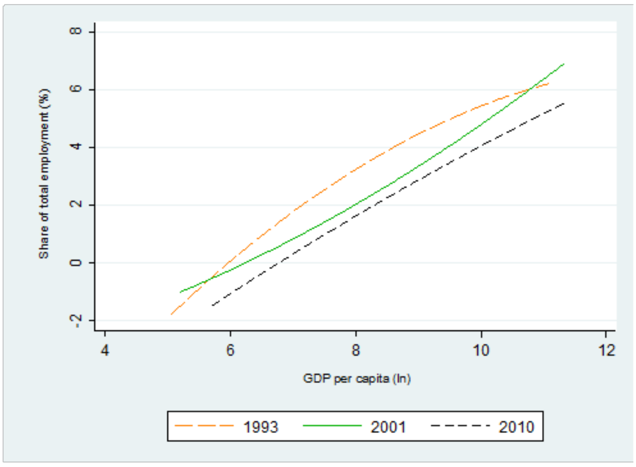
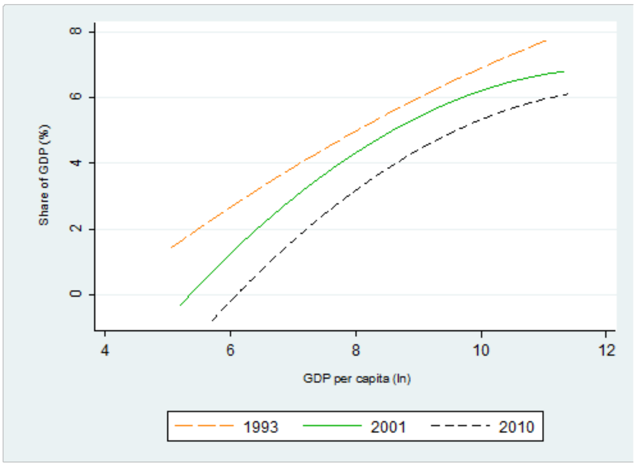


Figure 5f: Share of high-tech manufacturing in GDP, 1993-2001-2010



Next, in Figure 6 we consider the dynamics of specific sub-sectors of manufacturing. For reasons of brevity, instead of presenting all 17 sub-sectors, we show three prominent sub-sectors for each of the three categories of manufacturing.[10]

The heterogeneity evident in the earlier disaggregation by tech category is even clearer here. Moreover, not only is there extensive heterogeneity between tech categories, but also within sub-sectors in each tech category. For example, fabricated metals is at the more sophisticated end of the medium-tech category, and is increasing monotonically in shares of both employment and GDP for both points in time analysed, with no turning point in countries' range of GDP per capita.

Medical equipment can be considered one of the most specialised, technically sophisticated and high-tech sub-sectors of manufacturing (see Figures 8e and 8f). Medical equipment includes a wide range of critical product system-integrating complex sub-systems and technology platforms, including complex sensors, actuators, valves, fluidic system and advanced materials, all integrated through digital advanced solutions. As a result, the medical device sector tends to flourish in countries (and specific sub-regions) with advanced industrial ecosystems made of specialised contractors and global system integrators (Andreoni, 2018). As a result, the curves are distinctly convex for this sub-sector of manufacturing — not only is increasing income per capita associated with higher shares of medical equipment in both GDP and employment, it is even so at an increasing rate as income per capita increases. This is indicative of the high-level productive, technological and organisational capabilities required for success in the manufacturing of medical equipment.

This underscores the point that not only can high-income countries be competitive in certain segments of manufacturing, but that — notwithstanding overall deindustrialisation — these segments of manufacturing can account for higher shares of countries' GDP and employment than for less-advanced economies. Moreover, the fact that the employment dynamic does not reach a tipping point, even in the case of the automotive sector, suggests that, despite the high-tech nature of these sectors and the introduction of automated solutions in production, these sectors can generate high-wage manufacturing employment.[11]

Furthermore, there are differences in the shifts between curves over time for the various sub-sectors, which we illustrate with selected examples here. For low-tech sectors, there is a clear drop from 1993 to 2010. For both clothing and textiles, their share of GDP (Figures 6b and 6d) changes to a monotonically decreasing curve by 2010; i.e. the share of clothing and of textiles in GDP does not rise even in low- to lower-middle income countries. The share of auto manufacturing in GDP (Figure 8d) is a convex curve in 1993, indicating that it increased at an increasing rate with GDP per capita, but by 2010 it had become concave (although lacking a real

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[10] Full descriptions of the selected sub-sectors are as follows. For low-tech (Figure 6), 'Apparel' = Wearing apparel, fur (18) and Leather, leather products and footwear (19); 'Textiles' = Textiles (17); and 'Food & beverages' = Food and beverages (15) and Tobacco products (16). For medium-tech (Figure 7), 'Rubber and plastics' = Rubber and plastic products (25); 'Basic metals' = Basic metals (25); and 'Fabricated metals' = Fabricated metal products (28). For high-tech (Figure 8), 'Electrical machinery and electronics' = Electrical machinery and apparatus (31) and Radio, television and communication equipment (32); 'Auto' = Motor vehicles, trailers, semi-trailers (34) and Other transport equipment (35); and 'Medical equipment' = Medical, precision and optical instruments (33).

[11] See Andreoni and Anzolin (2019) for a discussion of the diffusion of robotisation in manufacturing.

downward sloping section over the country range of GDP per capita), possibly reflecting the growing importance of auto production in some middle-income countries.

Figure 6: Selected low-tech sub-sectors

Figure 6a: Share of apparel in total employment, 1993 and 2010

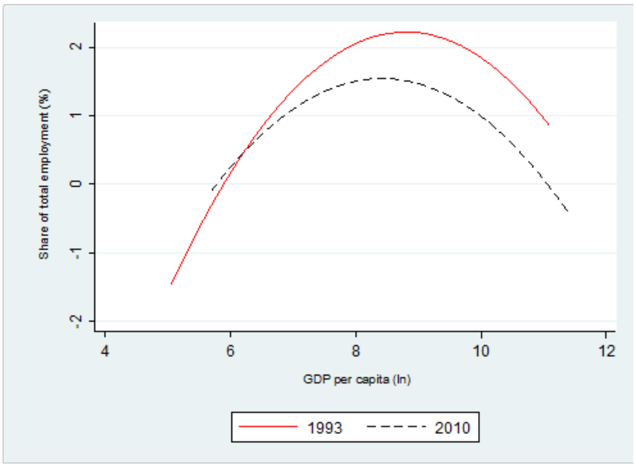


Figure 6b: Share of apparel in GDP, 1993 and 2010

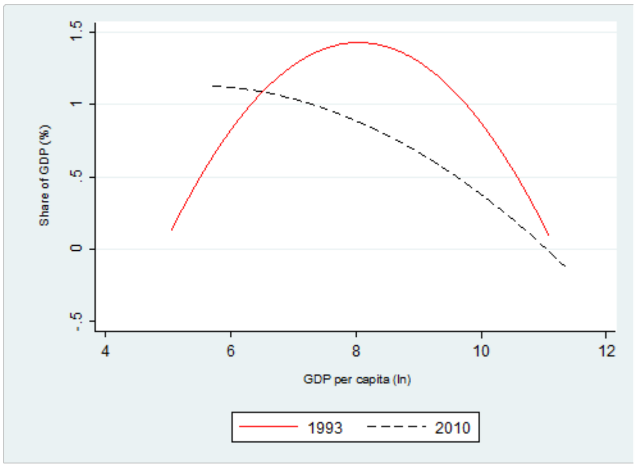


Figure 6c: Share of textiles in total employment, 1993 and 2010

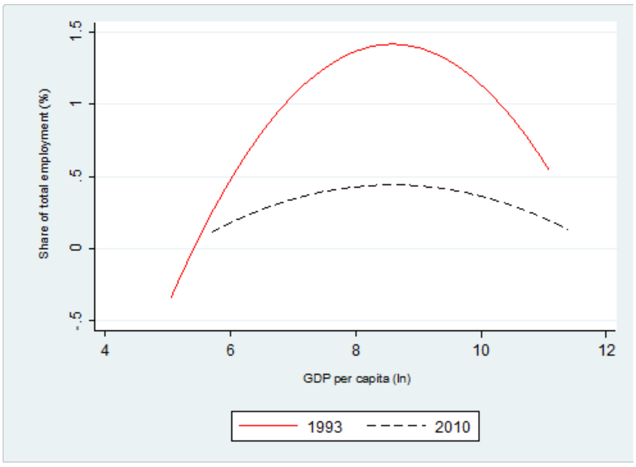


Figure 6d: Share of textiles in GDP, 1993 and 2010

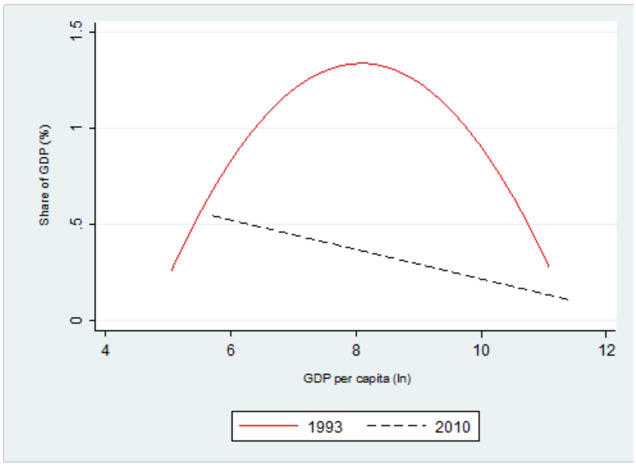


Figure 6e: Share of food and beverages in total employment, 1993 and 2010

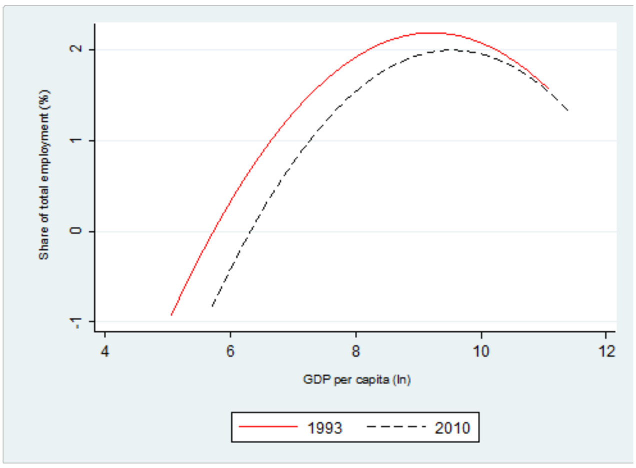


Figure 6f: Share of food and beverages in GDP, 1993 and 2010

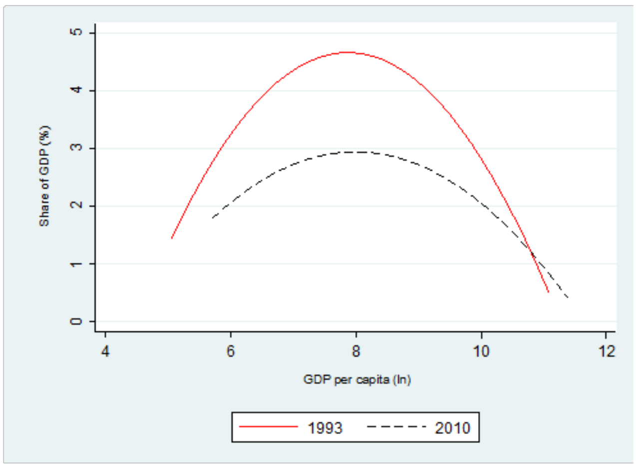


Figure 7: Selected medium-tech sub-sectors

Figure 7a: Share of rubber and plastics in total employment, 1993 and 2010

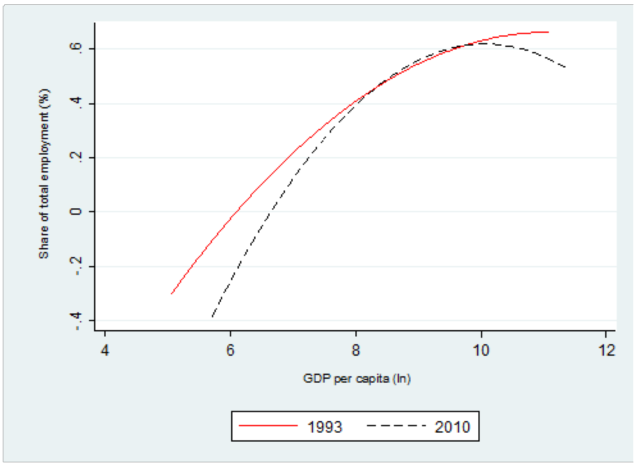


Figure 7b: Share of rubber and plastics in GDP, 1993 and 2010

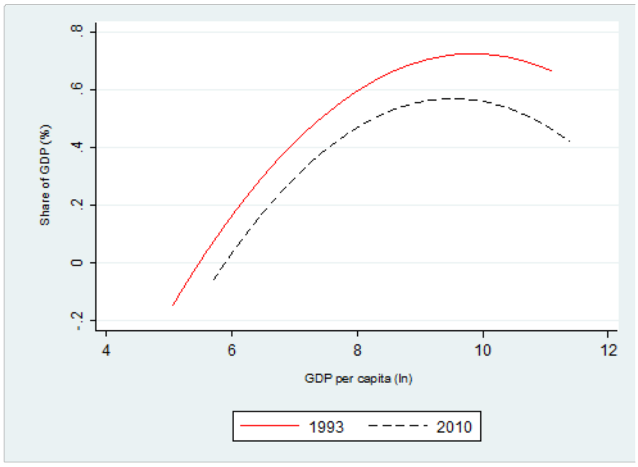


Figure 7c: Share of basic metals in total employment, 1993 and 2010

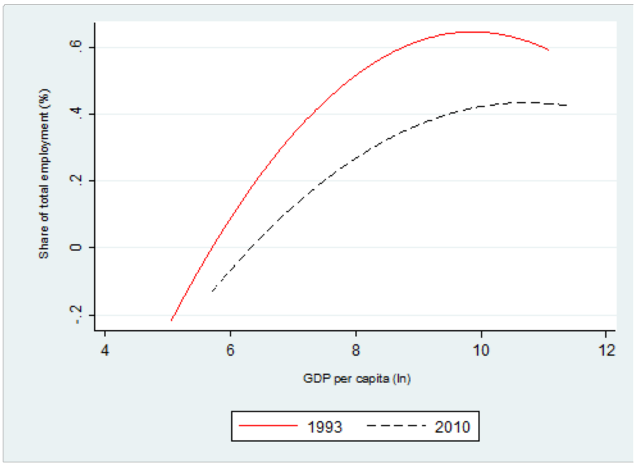


Figure 7d: Share of basic metals in GDP, 1993 and 2010

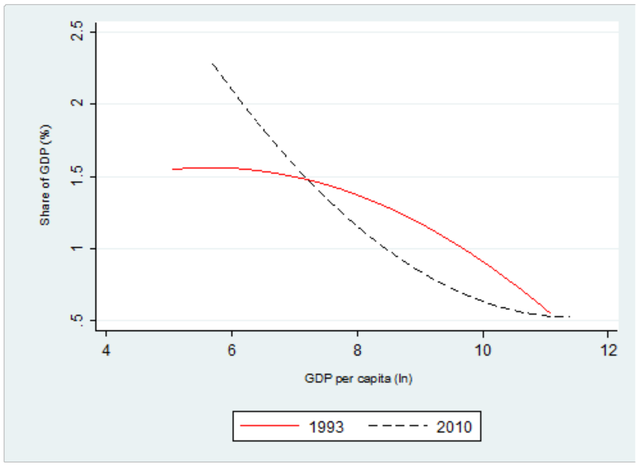


Figure 7e: Share of fabricated metals in total employment, 1993 and 2010

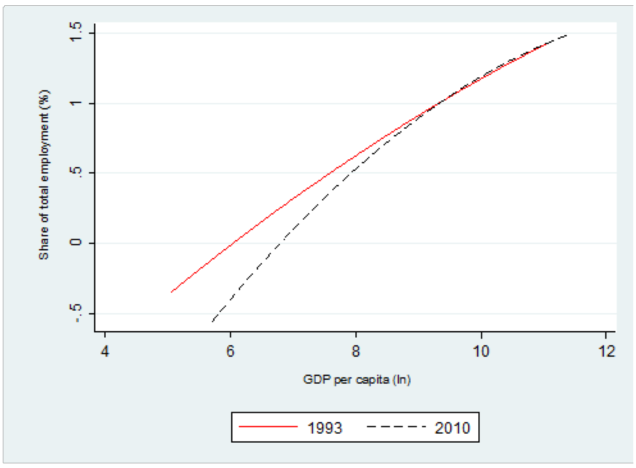


Figure 7f: Share of fabricated metals in GDP, 1993 and 2010

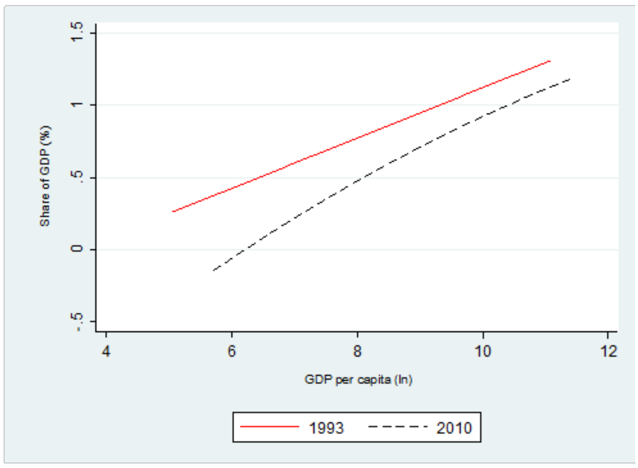


Figure 8: Selected high-tech sub-sectors

Figure 8a: Share of electrical machinery and electronics in total employment, 1993 and 2010

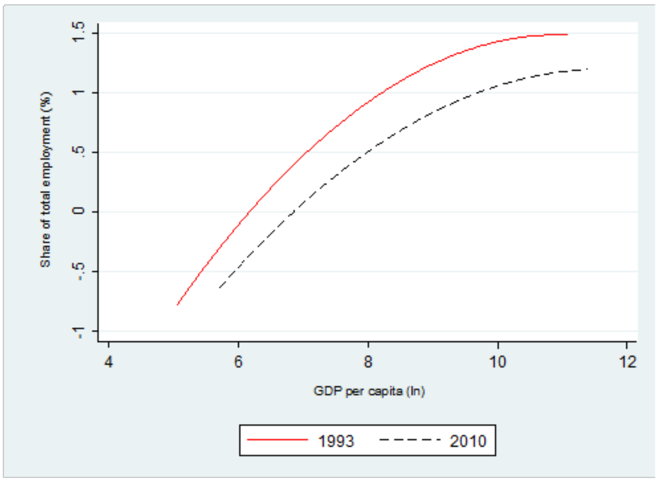


Figure 8b: Share of electrical machinery and electronics in GDP, 1993 and 2010

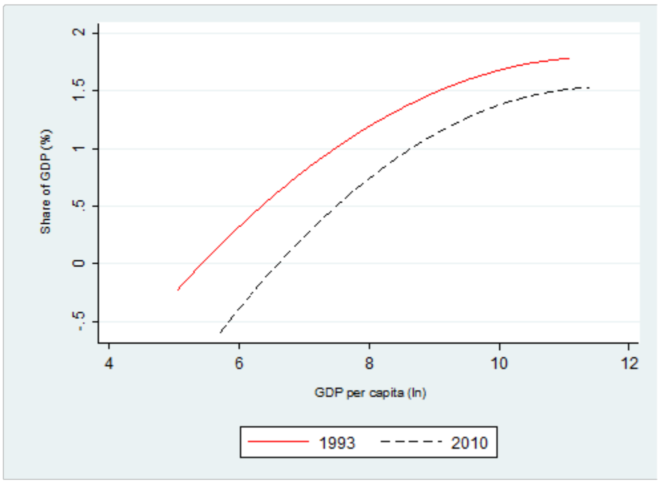


Figure 8c: Share of auto in total employment, 1993 and 2010

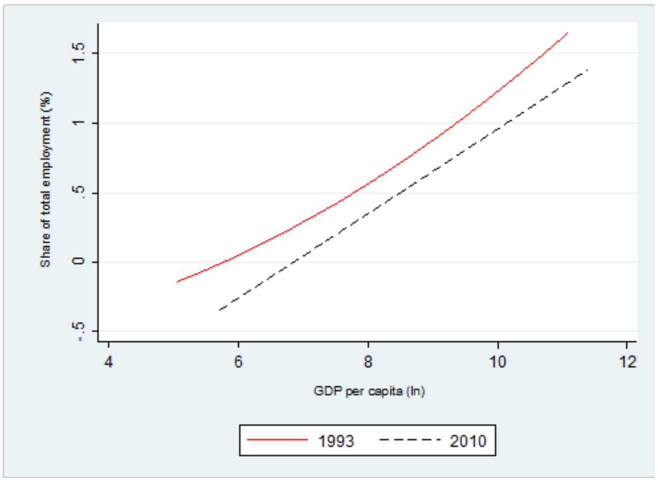


Figure 8d: Share of auto in GDP, 1993 and 2010

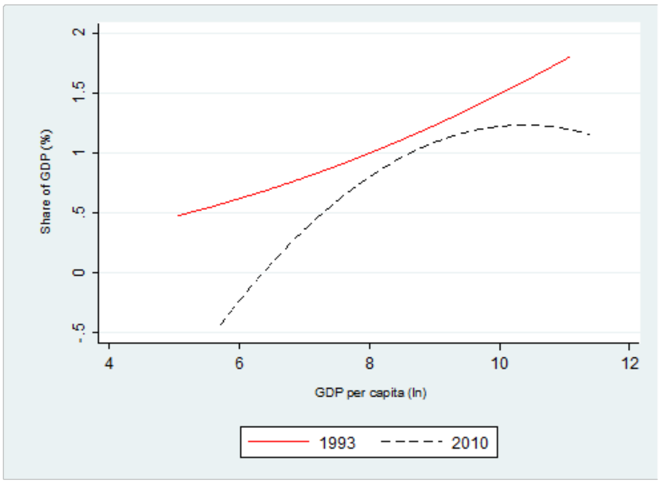


Figure 8e: Share of medical equipment in total employment, 1993 and 2010

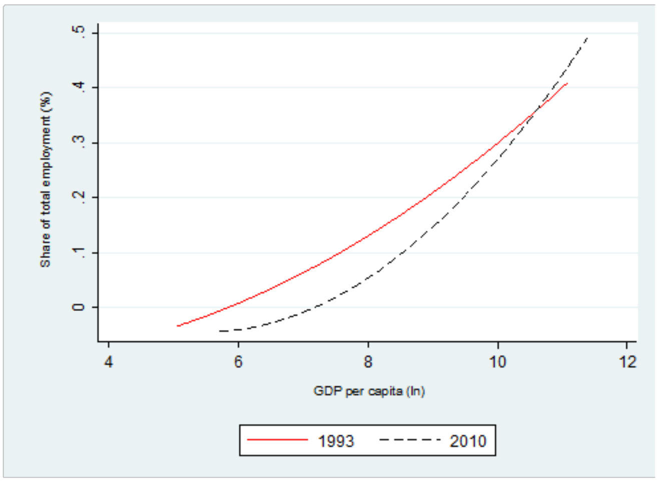
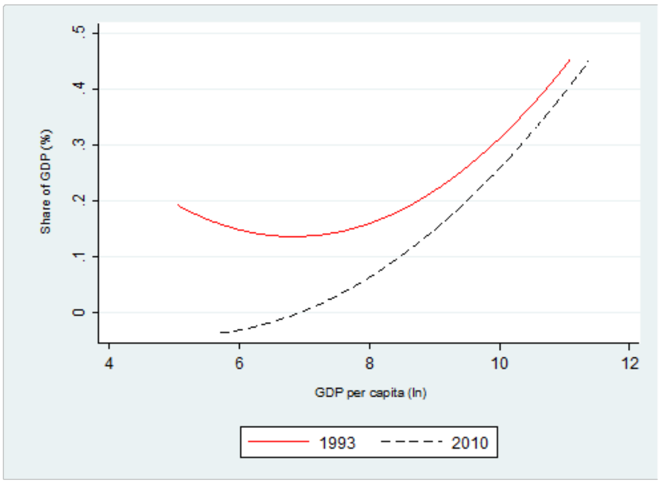


Figure 8f: Share of medical equipment in GDP, 1993 and 2010



Next, in Figure 9 we reproduce the dynamic analysis and typology of country trajectories shown in Figure 3 for aggregate manufacturing, but here focusing specifically on high-tech manufacturing.[12] The previous interpretation of quadrants also applies here — ahead and speeding, ahead but slowing, behind and slowing, and behind but speeding — but in terms of high-tech manufacturing specifically. This is especially important for understanding countries' success in moving into more advanced manufacturing, which is crucial for sustained high rates of productivity growth. For advanced economies, competitiveness in high-tech manufacturing is instrumental in maintaining an industrial sector and for growth more broadly. For developing countries, moving into high-tech manufacturing is critical for the process of catching up, as high-tech sectors have greater depth and scope for value creation, value capture and technological change.

As might be expected, it is mainly industrialised and emerging industrial economies whose shares of high-tech manufacturing in employment and GDP is higher than would be expected based on their income per capita. Few least-developed countries and other developing countries are in the top two 'ahead' quadrants, with one exception being Ethiopia in terms of employment shares (Figure 9a).

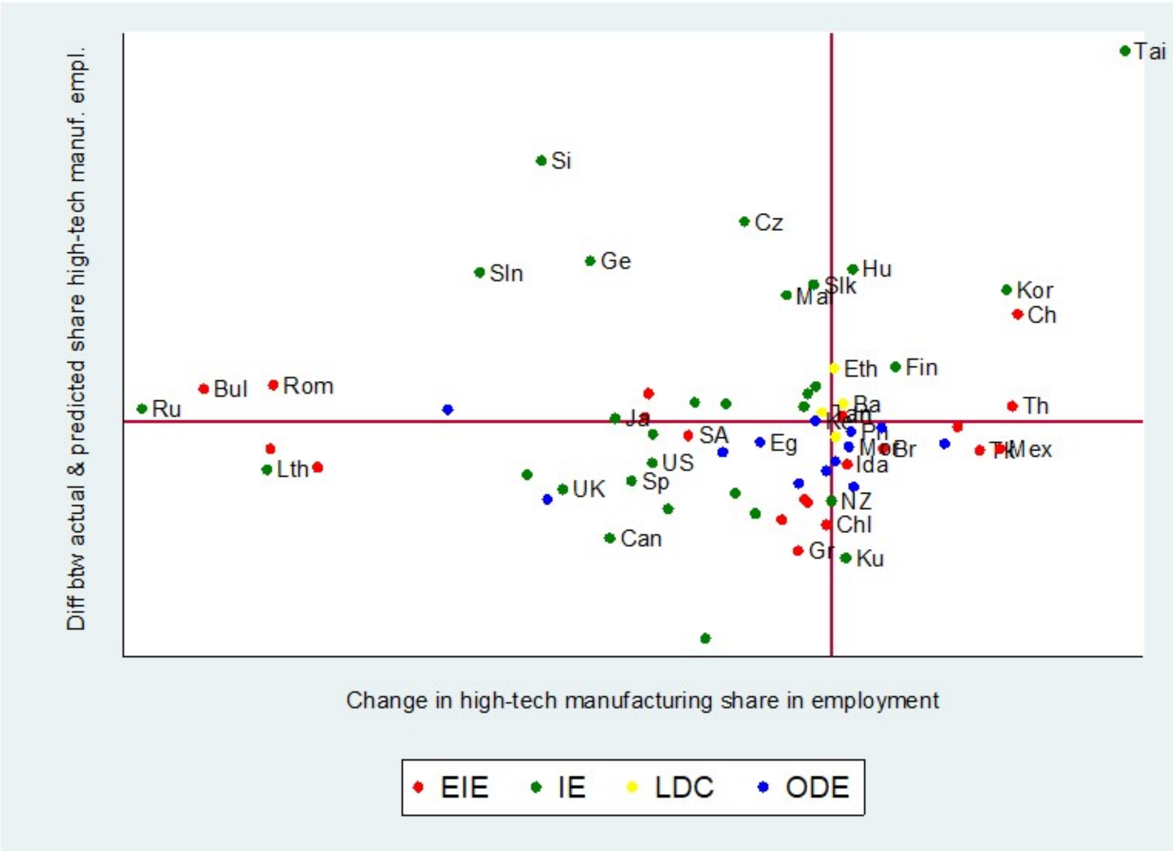
Geographically, it is East Asia that comes out best here, with Taiwan (province of China) and the Republic of Korea as star performers in the 'ahead and speeding' quadrant. Indeed, even in terms of shares of high-tech manufacturing in GDP and employment, without taking income per capita into account, Taiwan (province of China) ranks first in employment share and second to Korea in GDP share. Thailand, Singapore and China also present favourably here (notwithstanding the decline in the share of high-tech manufacturing in China's GDP, and in Singapore for both shares of GDP over the period of analysis). These results bolster the expectation that East Asian countries will continue to grow their manufacturing competitiveness and high rates of economic growth relative to the rest of the world.

Among Western European countries, Germany and Finland both have shares of high-tech manufacturing above the already-high shares that would be predicted based on their income per capita, reflecting their relatively strong and dynamic manufacturing sectors. Interesting, we also find a number of East European countries having higher than expected shares of high-tech manufacturing in both employment and GDP and, in the case of Hungary, this is combined with strong growth as a share of both employment and GDP as well. This may reflect the fact that, even though Eastern European countries have dramatically deindustrialised over the past three decades, their levels of productive capabilities remain high for their current levels of income per capita. Furthermore, some Central and Eastern European countries are integrated with, for example, the German auto industry through supply chains, and their relatively high auto production (especially in Hungary, as well as in the Czech Republic) manifests here in strong performance in high-tech manufacturing.

[12] The underlying specifications for Figure 9 are linear, as these are a better fit than the quadratic specifications for high-tech manufacturing (see also the shape of the high-tech lines in Figure 4).

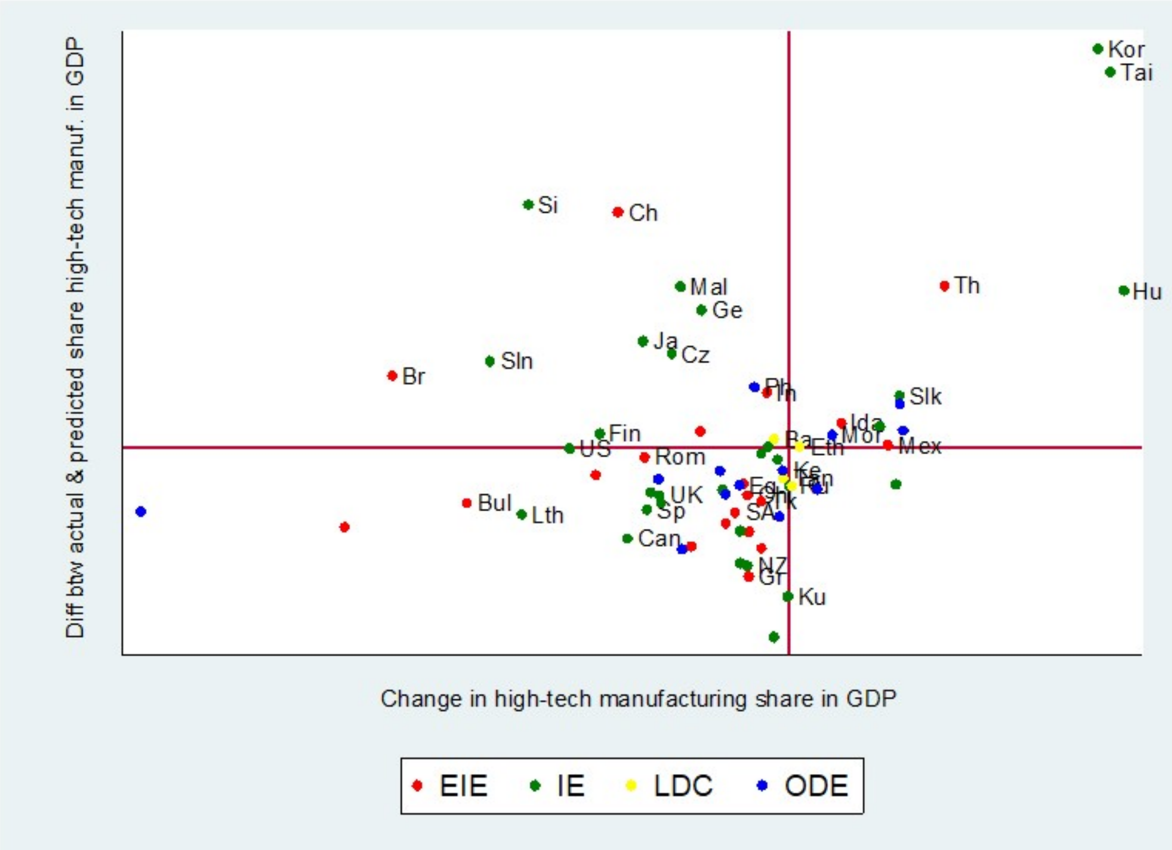
Countries in the 'behind and slowing' quadrant in both figures 9a and 9b include advanced economies such as the UK, Spain and Canada, as well as stagnant, middle-income economies such as South Africa. To be in this quadrant for high-tech manufacturing in particular bodes ill for the prospects of sustained economic growth.

Figure 9a: Scatterplot of country results — high-tech manufacturing in shares of employment



Notes: Ar = Argentina; Ba = Bangladesh; Br = Brazil; Cam = Cambodia; Chl = Chile; Ch = China; Eth = Ethiopia; Fin = Finland; Fr = France; Ge = Germany; Ind = India; Ida = Indonesia; Ja = Japan; Ke = Kenya; Kor = Korea; Mal = Malaysia; Mex = Mexico; My = Myanmar; Ni = Nigeria; Pak = Pakistan; Par = Paraguay; Ph = Philippines; Ru = Russia; Rw = Rwanda; SA = South Africa; Sp = Spain; Th = Thailand; Tk = Turkey; UK = United Kingdom; US = United States; Ur = Uruguay; Vi = Vietnam; Zim = Zimbabwe.
EIE = emerging industrial economies; IE = industrialised economies; LDC = least developed countries; ODE = other developing economies.
Each point in this scatterplot indicates a country's change in the share of high-tech manufacturing in total employment (x-intercept) and the difference between actual and predicted share of high-tech manufacturing in total employment (y-intercept).

Figure 9b: Scatterplot of country results — high-tech manufacturing in shares of GDP



Notes: Country key and industrial groups as in Figure 9a.

Each point in this scatterplot indicates a country's change in the share of high-tech manufacturing in GDP (x-intercept) and difference between actual and predicted share of high-tech manufacturing in GDP (y-intercept).

5. Conclusions

In this paper we set out to provide new evidence for an analysis of premature deindustrialisation that takes into account the changing nature of the well-known inverted-U relationship between GDP and the shares of manufacturing in total employment and GDP. The key findings emerging from our empirical analysis can be summarised in terms of patterns across sub-sectors, changes over time and patterns across countries, as follows.

Firstly, the results bring to light the extraordinary heterogeneity within manufacturing. Not only are there significant differences between low, medium and high-tech manufacturing, but there is also considerable variation among the sub-sectors within each of these categories. While manufacturing as a whole exhibits an inverted-U curve of industrialisation and deindustrialisation, this is not the case for all activities within manufacturing. The differences observed across manufacturing sub-sectors are analytically intuitive. Overall, the more specialised, sophisticated and high-tech a manufacturing activity, the less concave is its pattern of development, becoming a monotonically increasing line and even a convex curve for very high-tech sub-sectors such as medical equipment. Thus, we point to a stylised fact that the more high-tech a manufacturing activity, the less is the decline with rising income per capita, with shares even increasing for very high-tech activities. It is also interesting to note that this relationship stands even in the case of capital- and robot-intensive sectors such as automotive production, suggesting that premature deindustrialisation does not necessarily have to lead to a reduction in employment. These results also underscore the importance, both analytically and for policy, of one of the key premises of this paper: drilling down below the overall inverted-U to explore the diverse dynamics of industrialisation and deindustrialisation at the sub-sectoral level.

In terms of changes over time, for manufacturing in aggregate our results on balance confirm the shift downward (i.e. deindustrialisation setting in at lower shares of manufacturing in GDP and employment), as well as leftward (i.e. deindustrialisation setting in at lower levels of GDP per capita, at least in terms of our employment results). Not only do the static patterns differ widely across sub-sectors, as discussed above, but there is also heterogeneity in changes over time by sub-sector. The curves of low-tech sub-sectors fall and shift leftwards over time, and for some sub-sectors (and especially in their shares of GDP) there is a transition from an inverted-U to a monotonically decreasing curve, with no range of countries' GDP per capita at which their share of this manufacturing in GDP increases. In high-tech sub-sectors, by contrast, the curve in some cases becomes, if anything, more convex, while in other cases it switches from slightly convex to slightly concave as middle-income countries become increasingly competitive (e.g. in auto).

It is also worth noting that shifts in curves across time are accounted for not only by changes in production patterns across countries, but also by changes in the nature of production and of products within sub-sectors. While the designations and classifications of sectors may remain constant over time, there are important changes in their technological content and production platforms. Curves for the same notional sub-sector at different points in time are thus comparing different aggregations of activities. Shifts over time thus reflect both these changes, and changes in the international distribution of production, which are of course interrelated. This observation is particularly important, as it challenges the analytical and empirical grounds of very long-term cross-country regression analyses aimed at extracting normal patterns of structural change.

Thirdly, our analysis demonstrates the diversity of country experiences of industrialisation and deindustrialisation, both for manufacturing in aggregate and at the sub-sectoral level. Our typology of country patterns — *ahead and speeding*, *ahead but slowing*, *behind and slowing*, and *behind but speeding* — seeks to characterise this diversity in a meaningful way, based on the two dimensions of (1) changes in manufacturing shares of GDP and employment and (2) whether countries' manufacturing shares are above or below the expectation based on their income per capita. The empirical analysis yields interesting country patterns, including by region, and combines indicators capturing both structural features (manufacturing shares — ahead or behind the benchmark) and structural dynamics (manufacturing growth). It also draws attention to the importance of looking not just at countries' manufacturing shares over time, but also at how these shares compare with other countries based on the metric of income per capita.

This analytical framework also provides the basis for the working definition of premature deindustrialisation that we propose here and apply empirically to identify possible premature deindustrialisers. In broad terms, we conceptualise premature deindustrialisation as deindustrialisation setting in at lower manufacturing shares and lower levels of GDP per capita than would be expected based on international patterns. More formally, within the framework of this analysis, we define possible premature deindustrialisers as countries whose share of GDP and/or employment is falling, with the country located both below the curve and to the left of the turning point. Twenty-one countries meet these criteria for both employment shares and GDP shares in our analysis; we emphasise that this identification is indicative rather than conclusive.

Applying a similar method to high-tech manufacturing also enriches our understanding of which countries are ahead, behind, slowing down and speeding up in terms of their shares of high-tech manufacturing specifically. This is especially relevant given the importance of high-tech manufacturing for innovation, R&D, knowledge spill-overs, upgrading and growth in productivity and competitiveness across sectors of any economy. Taiwan (province of China), Korea, Thailand and Hungary are examples exhibiting higher shares of high-tech manufacturing in both GDP and total employment than would be expected based on their levels of income per capita, with these shares growing further; China and Finland are additional examples for the part of the analysis on employment shares. By contrast, countries such as Greece, the United Kingdom, Egypt and South Africa are 'behind and slowing' with regard to high-tech manufacturing, which bodes ill for their growth prospects. It is interesting to point out that, while a country such as the United Kingdom might often be considered ahead in terms of patents and innovation in high-tech industries, our analysis reveals how these innovation activities do not necessarily translate into manufacturing dynamics of growth. In other words, our analysis reveals countries in which the production-innovation nexus has been broken.

One policy implication emerging from this analysis is the need to underscore that even high-income economies can increase their shares of GDP and/or employment in some sub-sectors of manufacturing. In particular, superior productive capabilities in advanced economies give them a competitive advantage in high-tech manufacturing. Rather than these countries giving up on manufacturing as a whole, they can build up their manufacturing in segments in which they have a competitive advantage, especially in high-tech manufacturing.

Different sub-sectors within manufacturing have varying capacities to 'pull along' wider economic growth. These results point to the importance of targeted policy responses that take into account the specificities of deindustrialisation in particular countries, rather than 'one-size-fits-all' policies. In particular, 'under-industrialisation' and 'deindustrialisation' in high-tech sectors raise concerns for countries' growth and development, and merit decisive responses through industrial and other policies, including the targeting of particular sub-sectors of manufacturing.

This analysis provides a rich basis for various possible extensions and future research. Dynamic scatterplots, similar to those in Figures 3 and 9 but with more than one point per country, could illuminate countries' trajectories over time. Furthermore, while we have grouped countries here by region and by industrialisation category, we can also group countries according to other relevant categories, such as manufacturing export orientation or income category. More recent data would also allow us to update the analysis. In addition to analysing manufacturing shares of GDP and of total employment, we can also analyse manufacturing (and sub-sectoral) shares of exports. We also consider supplementing the manufacturing shares metric with an additional measure of manufacturing value added per manufacturing worker (or shares of world manufacturing normalised by population), by sub-sector. A further extension could entail a causal analysis of how the cross-country differences identified here affect growth outcomes; we hypothesise that having growth in manufacturing shares as well as having shares higher than would be expected — and more so for high-tech manufacturing — will positively affect growth in subsequent periods. Finally, we consider linking concentration/diversification within manufacturing with premature deindustrialisation.

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Appendix

Table A1 lists all countries included in the empirical analysis. Countries marked with * are also included in the smaller sample used in the sub-sectoral analysis. Taiwan (province of China) is the only territory included in the sub-sectoral analysis but not in the overall manufacturing analysis.

Table A1: Country sample and classifications

Country	Region	Income group	Level of industrialisation
Afghanistan	SA	L	LDC
Albania	ECA	UM	ODE
Algeria	MENA	UM	ODE
Angola	SSA	LM	ODE
Argentina	LAC	UM	EIE
Armenia	ECA	UM	ODE
Australia	EAP	H	IE
Austria *	ECA	H	IE
Azerbaijan *	ECA	UM	ODE
Bahamas	LAC	H	ODE
Bahrain	MENA	H	IE
Bangladesh *	SA	LM	LDC
Barbados	LAC	H	ODE
Belarus	ECA	UM	EIE
Belgium *	ECA	H	IE
Belize	LAC	UM	ODE
Benin	SSA	L	LDC
Bhutan	SA	LM	LDC
Bolivia *	LAC	LM	ODE
Bosnia and Herzegovina *	ECA	UM	ODE
Botswana	SSA	UM	ODE
Brazil *	LAC	UM	EIE
Brunei Darussalam	EAP	H	EIE
Bulgaria *	ECA	UM	EIE
Burkina Faso	SSA	L	LDC
Burundi	SSA	L	LDC
Cambodia	EAP	L	LDC
Cameroon	SSA	LM	ODE
Canada *	NA	H	IE
Cape Verde	SSA	LM	ODE
Central African Republic	SSA	L	LDC
Chad	SSA	L	LDC
Chile *	LAC	H	EIE
China *	EAP	UM	EIE
Colombia *	LAC	UM	EIE
Comoros	SSA	LM	LDC
Congo	SSA	LM	ODE

Country	Region	Income group	Level of industrialisation
Congo, Democratic Republic of the	SSA	L	LDC
Costa Rica *	LAC	UM	EIE
Côte d'Ivoire	SSA	LM	ODE
Croatia *	ECA	H	EIE
Cuba	LAC	UM	ODE
Cyprus	ECA	H	EIE
Czech Republic *	ECA	H	IE
Denmark *	ECA	H	IE
Djibouti	MENA	LM	LDC
Dominican Republic	LAC	UM	ODE
Ecuador *	LAC	UM	ODE
Egypt *	MENA	LM	ODE
El Salvador	LAC	LM	ODE
Equatorial Guinea	SSA	UM	ODE
Eritrea	SSA	L	LDC
Estonia	ECA	H	IE
Ethiopia *	SSA	L	LDC
Fiji	EAP	UM	ODE
Finland *	ECA	H	IE
France *	ECA	H	IE
French Polynesia	EAP	H	IE
Gabon	SSA	UM	ODE
Gambia	SSA	L	LDC
Georgia	ECA	UM	ODE
Germany	ECA	H	IE
Ghana	SSA	LM	ODE
Greece *	ECA	H	EIE
Guatemala	LAC	UM	ODE
Guinea	SSA	L	LDC
Guinea-Bissau	SSA	L	LDC
Guyana	LAC	UM	ODE
Haiti	LAC	L	LDC
Honduras	LAC	LM	ODE
Hong Kong, China	EAP	H	IE
Hungary *	ECA	H	IE
Iceland	ECA	H	IE
India *	SA	LM	EIE
Indonesia *	EAP	LM	EIE
Iran *	MENA	UM	ODE
Iraq	MENA	UM	ODE
Ireland *	ECA	H	IE
Israel *	MENA	H	IE
Italy *	ECA	H	IE

Country	Region	Income group	Level of industrialisation
Jamaica	LAC	UM	ODE
Japan *	EAP	H	IE
Jordan	MENA	UM	ODE
Kazakhstan	ECA	UM	EIE
Kenya *	SSA	LM	ODE
Korea, Republic of *	EAP	H	IE
Kuwait *	MENA	H	IE
Kyrgyzstan *	ECA	LM	ODE
Lao	EAP	LM	LDC
Latvia *	ECA	H	EIE
Lebanon	MENA	UM	ODE
Lesotho	SSA	LM	LDC
Liberia	SSA	L	LDC
Libya	MENA	UM	ODE
Lithuania	ECA	H	IE
Luxembourg	ECA	H	IE
Macao, China *	EAP	H	IE
Macedonia *	ECA	UM	EIE
Madagascar	SSA	L	LDC
Malawi *	SSA	L	LDC
Malaysia *	EAP	UM	IE
Maldives	SA	UM	ODE
Mali	SSA	L	LDC
Malta	MENA	H	IE
Mauritania	SSA	LM	LDC
Mauritius *	SSA	UM	EIE
Mexico *	LAC	UM	EIE
Moldova, Republic of	ECA	LM	ODE
Mongolia	EAP	LM	ODE
Montenegro	ECA	UM	ODE
Morocco *	MENA	LM	ODE
Mozambique	SSA	L	ODE
Myanmar	EAP	LM	LDC
Namibia	SSA	UM	ODE
Nepal	SA	L	LDC
Netherlands *	ECA	H	IE
New Caledonia	EAP	H	IE
New Zealand *	EAP	H	IE
Nicaragua	LAC	LM	ODE
Niger	SSA	L	LDC
Nigeria	SSA	LM	ODE
Norway *	ECA	H	IE
Occupied Palestinian Territory	MENA	LM	ODE

Country	Region	Income group	Level of industrialisation
Oman	MENA	UM	EIE
Pakistan	SA	LM	ODE
Panama	LAC	H	ODE
Papua New Guinea	EAP	LM	ODE
Paraguay *	LAC	UM	ODE
Peru *	LAC	UM	ODE
Philippines *	EAP	LM	ODE
Poland *	ECA	H	EIE
Portugal *	ECA	H	IE
Puerto Rico	LAC	H	IE
Qatar	MENA	H	IE
Romania *	ECA	UM	EIE
Russian Federation	ECA	UM	IE
Rwanda	SSA	L	LDC
Saint Lucia	LAC	UM	ODE
Saint Vincent and the Grenadines	LAC	UM	ODE
Samoa	EAP	UM	LDC
Sao Tome and Principe	SSA	LM	LDC
Saudi Arabia *	MENA	H	EIE
Senegal *	SSA	LM	LDC
Serbia	ECA	UM	EIE
Sierra Leone	SSA	L	LDC
Singapore *	EAP	H	IE
Slovakia	ECA	H	IE
Slovenia *	ECA	H	IE
Solomon Islands	EAP	LM	LDC
Somalia	SSA	L	LDC
South Africa *	SSA	UM	EIE
Spain *	ECA	H	IE
Sri Lanka *	SA	UM	ODE
Suriname	LAC	UM	EIE
Swaziland	SSA	LM	ODE
Sweden *	ECA	H	IE
Switzerland	ECA	H	IE
Syrian Arab Republic	MENA	L	ODE
Taiwan (province of China) *	EAP	H	IE
Tajikistan	ECA	L	ODE
Thailand *	EAP	UM	EIE
Timor-Leste	EAP	LM	LDC
Togo	SSA	L	LDC
Tonga	EAP	UM	ODE
Trinidad and Tobago	LAC	H	ODE
Tunisia	MENA	LM	EIE

Country	Region	Income group	Level of industrialisation
Turkey *	ECA	UM	EIE
Turkmenistan	ECA	UM	ODE
Uganda	SSA	L	n/a
Ukraine	ECA	LM	EIE
United Arab Emirates	MENA	H	IE
United Kingdom *	ECA	H	IE
United Republic of Tanzania *	SSA	L	LDC
United States *	NA	H	IE
Uruguay *	LAC	H	EIE
Uzbekistan	ECA	LM	ODE
Vanuatu	EAP	LM	LDC
Venezuela	LAC	UM	EIE
Viet Nam	EAP	LM	ODE
Yemen	MENA	L	LDC
Zambia	SSA	LM	LDC
Zimbabwe	SSA	LM	ODE

Notes: Region is based on World Bank classification. EAP = East Asia and Pacific; ECA = Europe and Central Asia; LAC = Latin America and the Caribbean; MENA = Middle East and North Africa; NA = North America; SA = South Asia; SSA = sub-Saharan Africa

Income group is based on the World Bank's most recent country classification (2018). L = Low income; LM = Lower middle income; UM = Upper middle income; H = High income

Level of industrialisation is based on UNIDO classification (see Upadhyaya, 2013). IE = Industrialised economies; EIE = Emerging industrial economies; ODE = Other developing economies; LDC = Least developed countries.

* denotes countries also included in the sub-sectoral analysis.

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