Structural Change and Economic Dynamics 34 (2015) 46–59

Contents lists available at ScienceDirect

Structural Change and Economic Dynamics

journal homepage: www.elsevier.com/locate/sced

Manufacturing and economic growth in developing countries, 1950–2005

Adam Szirmai[a,*], Bart Verspagen[a,b]

[a] Maastricht Economic and Social Research and Training Centre on Innovation and Technology, United Nations University (UNU-MERIT), Maastricht, The Netherlands

[b] School of Business and Economics, Maastricht University, Maastricht, The Netherlands

ARTICLE INFO

Article history:
Received October 2013
Received in revised form June 2015
Accepted June 2015
Available online 8 July 2015

Keywords:
Economic growth
Development
Industrialisation
Manufacturing sector

JEL classification:
O10
O14
O40

ABSTRACT

Historically, manufacturing has functioned as the main engine of economic growth and development. However, recent research raises questions concerning the continued importance of the manufacturing sector for economic development. We re-examine the role of manufacturing as a driver of growth in developed and developing countries in the period 1950–2005. We find a moderate positive impact of manufacturing on growth. We also find interesting interaction effects of manufacturing with education and income gaps. In a comparison of the subperiods, it seems that since 1990, manufacturing is becoming a more difficult route to growth than before.

1. Introduction

This paper addresses the question of the importance of manufacturing for economic development. In the older literature, there was a near-consensus that manufacturing was the high road to development. Success in economic development was seen as synonymous with industrialisation. This consensus now seems to be unravelling. In advanced countries, service sectors account for over two thirds of GDP. This alone gives the service sector a heavy weight in economic growth in the advanced economies. In developing countries the share of services is also substantial. It is now argued that services sectors such as software, business processing, finance or tourism may act as leading sectors in development and that the role of manufacturing is declining. The prime exemplar for this perspective is India since the 1990s (Dasgupta and Singh, 2005). Other authors argue that it is not manufacturing as a whole that is important, but subsectors of manufacturing such as Information and Communications Technology (Fagerberg and Verspagen, 1999; Jorgenson et al., 2005).

On the other hand, the East Asian experience documents the key role that industrialisation has played in the economic development of developing countries in the past fifty years[1]. Further, all historical examples of success

* Corresponding author at: UNU-MERIT, PO Box 616, NL-6200MD Maastricht, The Netherlands. Tel.: +31 43 3884469.

E-mail addresses: szirmai@merit.unu.edu (A. Szirmai), verspagen@merit.unu.edu (B. Verspagen).

[1] When we speak about industrialisation in this paper we explicitly focus on the role of manufacturing. In the ISIC classifications the industrial sector also includes mining, utilities and construction. Many papers on

http://dx.doi.org/10.1016/j.strueco.2015.06.002

in economic development and catch-up since 1870 have been associated with successful industrialisation (Szirmai, 2012).

This paper sets out to investigate the role of manufacturing in economic growth and development by testing econometrically whether manufacturing has led to economic growth in a large panel of countries during the post-war period. The proposition to be tested is that manufacturing had a significant positive effect on growth (in developing countries), and that this effect of manufacturing was stronger than that of other sectors, in particular the services sector. This is referred to as the engine of growth hypothesis. We employ a regression framework using a dataset of 88 countries, including 21 advanced economies and 67 developing countries, covering the period 1950–2005. Among other things, we investigate whether the role of manufacturing in growth has changed over time, thus addressing the above mentioned question about whether the role of manufacturing has recently been waning in favour of services. The novelty of the paper lies in applying state of the art panel data regression methods to a new large dataset with data on manufacturing shares going back to the 1950s. This provides new insights in the context of the ongoing debate about the importance of industrialisation.

The paper is structured as follows. The theoretical arguments for the Engine of Growth hypothesis are summarised in Section 2. Section 3 reviews some of the recent contributions in the literature. Section 4 details our precise research questions. Data and methods are discussed in Section 5. The empirical results are presented in Section 6. Section 7 concludes.

2. The engine of growth argument

The arguments for the engine of growth hypothesis are a mix of empirical and theoretical observations (for more detail, see Szirmai, 2012). There is an *empirical correlation* between the degree of industrialisation and the level of per capita income in developing countries (Kaldor, 1966, 1967; Rodrik, 2009). The developing countries which now have higher per capita incomes have seen the share of manufacturing in GDP and employment increase and have experienced dynamic growth of manufacturing output and manufactured exports. The poorest countries are invariably countries that have failed to industrialise and that still have very large shares of agriculture in GDP. In cross section analyses, the relationship between per capita GDP and share of industry or manufacturing is curvilinear rather than linear, with low levels of per capita GDP associated with low shares of manufacturing, intermediate levels with high shares and high income economies with lower shares (an inverted *U* shape, for example Rowthorn and Coutts, 2004; Rodrik, 2009). For developing countries this implies a positive relationship between GDP per capita and shares of manufacturing. The engine of growth hypothesis assumes that the correlation between levels of GDP per capita and shares of manufacturing results from characteristics of the manufacturing sector that make a special contribution to economic growth (Kaldor's first growth law, see Kaldor, 1966, 1967; Pacheco-López and Thirlwall, 2013). The arguments for a special role of industrialisation in the process of economic growth include the following.

First, it is argued that productivity is higher in the manufacturing sector than in the agricultural sector (Fei and Ranis, 1964; Syrquin, 1984, 1988). Manufacturing is also assumed to have more potential for productivity growth than other sectors. The transfer of resources from low productivity sectors such as traditional agriculture or informal services to high productivity and dynamic sectors such as manufacturing (i.e., industrialisation) provides a *structural change bonus*. This is a temporary effect on the growth rate, i.e., it lasts as long as the share of manufacturing is rising. Similarly, the transfer of resources from manufacturing to services may provide a *structural change burden* if many service activities indeed have little potential for productivity increase (Baumol, 1967). According to Baumol's law, aggregate per capita growth will tend to slow down as the share of services in GDP increases. Baumol's law has been contested in the more recent literature (Riddle, 1986; Timmer and de Vries, 2009; Marks, 2009; Inklaar et al., 2008; Triplett and Bosworth, 2006) but has definitely been part of the engine of growth argument in the past (Rostow, 1960; Gerschenkron, 1962; Kitching, 1982; Higgins and Higgins, 1979). Sectors such as transport, distribution and ICT services and other market services do have potential for productivity growth. But many service sectors such as personal services, health care services and government services are productivity resistant.

Next, compared to agriculture, the manufacturing sector is assumed to offer special *opportunities for capital accumulation*. Capital accumulation can be more easily realised in spatially concentrated manufacturing than in spatially dispersed agriculture and returns to capital (in terms of labour productivity or total factor productivity) are higher than in other sectors. Productive investment opportunities in manufacturing encourage the high savings rates that are characteristic of East Asian development Also investment spending is skewed towards manufactured goods such as machinery, equipment and building materials (Rowthorn and Coutts, 2004). These are among the reasons why the emergence of manufacturing has been so important in growth and development. Capital intensity is high not only in manufacturing but also in mining, utilities, construction and transport. It is much lower in agriculture and services. Capital accumulation is one of the aggregate sources of growth. Thus, an increasing share of manufacturing will contribute to aggregate growth. The engine of growth hypothesis implicitly argues that capital intensity in manufacturing is higher than in other sectors of the economy. Szirmai (2012) has shown that this is indeed the case for developing countries, but not in many advanced economies.

In the third place, the manufacturing sector offers special opportunities for *economies of scale*, which are less available in agriculture or services (Kaldor, 1966, 1967), and for both *embodied and disembodied technological progress* (Cornwall, 1977). The latter argument is of

industrialisation fail to make a clear distinction between industry and manufacturing (for example Rodrik, 2009).

particular importance. Technological advance is seen as being concentrated in the manufacturing sector and diffusing from there to other economic sectors such as the service sector. The capital goods that are employed in other sectors are produced in the manufacturing sector. It is also for this reason that in the older development economics literature the capital goods sector – machines to make machines – was given a prominent role (Mahanolobis, 1953).

Linkage and spillover effects are assumed to be stronger in manufacturing than in agriculture or mining. The idea of linkage effects refers to the direct backward and forward purchasing relations between different sectors and subsectors. Linkage effects create positive externalities to investments. Spillover effects refer to the disembodied knowledge flows between sectors. Spillover effects are a special case of externalities, related to investment in knowledge and technology. Linkage and spillover effects are presumed to be stronger for manufacturing than in other sectors (Hirschman, 1958). Intersectoral linkage and spillover effects between manufacturing and other sectors such as services or agriculture are also very powerful (see Cornwall, 1977; Park and Chan, 1989; Guerrieri and Meliciani, 2005).

The final argument refers to demand effects. As per capita incomes rise, the share of agricultural expenditures in total (consumption) expenditures declines due to low income elasticity and the share of expenditures on manufactured goods increases (*Engel's law*). Countries specialising in agricultural and primary production will therefore have a demand impediment to growth, unless they can profit from expanding world markets for manufacturing goods, i.e., industrialise. In recent years, a related argument has been made for services (Falvey and Gemmell, 1996; Iscan, 2010). As per capita incomes increase, the final and intermediate demand for services may increase. But for services that are not traded internationally, the increasing demand for services may be more a consequence of growing incomes and needs of other sectors than a driver of growth.

3. Review of the literature

The evidence for the engine of growth hypothesis in the literature is mixed. The older literature tends to emphasise the importance of manufacturing, the more recent literature finds that the contribution of the service sector has increased. Also, in the more recent literature one finds that manufacturing tends to be more important as an engine of growth in developing countries than in advanced economies and also more important in the period 1950–1973 than in the period after 1973.

Fagerberg and Verspagen (1999) regress real growth rates of GDP on growth rates of manufacturing. If the coefficient of manufacturing growth is higher than the share of manufacturing in GDP, this is interpreted as supporting the engine of growth hypothesis. Fagerberg and Verspagen find that manufacturing was typically an engine of growth in developing countries in East Asia and Latin America, but that there was no significant effect of manufacturing in the advanced economies.

In a second article Fagerberg and Verspagen (2002) examine the impact of shares of manufacturing and services on economic growth in three periods (1966–1972, 1973–1983 and 1984–1995) for a sample of 76 countries. They find that manufacturing has much more positive effects before 1973 than after. The interpretation in both papers is that the period 1950–1973 offered special opportunities for catch up through the absorption of mass production techniques in manufacturing from the USA. After 1973, ICT technologies started to become more important as a source of productivity growth, especially in the nineties. These technologies are no longer within the exclusive domain of manufacturing, but operate in the service sector.

Szirmai (2012) examines the arguments for the engine of growth hypothesis for a limited sample of Asian and Latin American developing countries. He focuses on capital intensity and growth of output and labour productivity. His results are again somewhat mixed. In general he finds support for the engine of growth hypothesis, but for some periods capital intensity in services and industry turns out to be higher than in manufacturing. In advanced economies productivity growth in agriculture is more rapid than in manufacturing.

Rodrik (2009) regresses growth rates of GDP for five-year periods on shares of industry in GDP in the initial year, following the same broad approach as we use below, but not distinguishing manufacturing from industry. He finds a significant positive relationship and interprets the growth of developing countries in the post-war period in terms of the structural bonus argument. He explicitly concludes that transition into modern industrial activities acts as an engine of growth. But he is rather vague about what he means by "modern." For Rodrik, structural transformation is the sole explanation of accelerated growth in the developing world.

For India recent papers reach contradictory conclusions. Katuria and Raj (2009) examine the engine of growth hypothesis at regional level for the recent period and conclude that more industrialised regions grow more rapidly. On the other hand, Thomas (2009) concludes that services have been the prime mover of growth resurgence in India since the 1990s. A similar position is taken by Dasgupta and Singh (2006). In an econometric analysis for India, Chakravarty and Mitra (2009) find that manufacturing is clearly one of the determinants of overall growth, but construction and services also turn out to be important, especially for manufacturing growth.

A recent article by Timmer and de Vries (2009) also points to the increasing importance of the service sector in a sample of countries in Asia and Latin America. Using growth accounting techniques, they examine the proportions of aggregate growth accounted for by different sectors in periods of growth accelerations, in periods of normal growth and in periods of deceleration. In periods of normal growth they find that manufacturing contributes most. In periods of growth acceleration, this leading role is taken over by the service sector, though manufacturing continues to have an important positive contribution.

Though it is obvious that services are becoming more important at higher levels of per capita income, there is a literature that argues for the continued importance of manufacturing, based on intersectoral linkages between manufacturing and service sectors. At more advanced levels of development there are increasingly strong linkages between manufacturing and service sectors, comparable to the balanced growth path relationships between agriculture and industrialisation at early stages of development (Szirmai, 2015). Service activities depend heavily on manufactured inputs. Manufacturing is also an important source of demand for modern intermediate service inputs such as financial services, transport and logistics and business services (Park, 2009; Park and Chan, 1989). But Park and Chan argue that the relations of dependence between manufacturing and services are asymmetric. Services depend more on manufacturing than vice versa. Also, the emergence of modern service activities depends on the structure of manufacturing. Some knowledge intensive manufacturing sectors such as office and computing machinery, electrical apparatus or industrial chemicals are the main users of producer services (Guerrieri and Meliciani, 2005). Disregarding intersectoral output and employment linkages will result in underestimation of the importance of the manufacturing sector for both growth and employment creation (UNIDO, 2013).

In sum, the existing literature presents a somewhat mixed picture. Manufacturing is seen as important in several papers, especially in the period 1950–1973 and in recent years more so in developing countries than in advanced economies. In the advanced economies, the contribution of the service sector has become more and more important and the share of services in GDP is now well above 70 per cent in the most advanced economies.

4. Research question

To guide our empirical analysis we take a strong version of the engine of growth hypothesis as our point of departure. We hypothesise that during the period 1950–2005 there is a positive and significant relationship between the share of manufacturing in GDP and the subsequent rate of growth of GDP per capita. This is the hypothesis that will guide our econometric analysis. We also want to investigate whether this effect of manufacturing on growth is conditioned by specific other factors, in particular the stage of development of a country and the education of the workforce.

We examine the hypothesis by regressing per capita GDP growth rates over five year periods (1950–1955, 1955–1960, and so forth) on manufacturing shares at the beginning of these five-year periods (1950, 1955, and so forth). We add the share of services at the beginning of the five year periods in order to compare manufacturing as an explanatory variable for growth, to services. If the coefficient of manufacturing shares is substantially higher than the coefficient of service sector shares, this is interpreted as support for the engine of growth argument. Also, if the coefficient of manufacturing share is significant and the coefficient of services is not, this is interpreted as support for the engine of growth argument. We also examine these relationships for different periods and different groups of countries. More specifically, we are interested in the question whether manufacturing is more important for growth in developing countries than other sectors, and whether the importance of manufacturing is declining over time as suggested by some of the existing literature.

Our theoretical discussion and review of the literature has put a causal structure from manufacturing, or industrialisation, to economic growth as the central argument. In our econometric work, which will commence in the next section, we will be restricted by the nature of our dataset where the direction of causality is concerned. Our data are a panel of countries and time periods, but with a limited number of variables. Although we will take some easy and obvious measures to avoid the most serious sources of simultaneity, such as measuring the explanatory variables at the beginning of the period for which growth is considered, there is no way in which our data will allow rigorous testing of the causal direction. Nevertheless, we feel that our econometric exercise has insights to offer with regard to the industrialisation debate, e.g., on the role of manufacturing vs. services, on the factors that facilitate industrialisation, and on the co-occurence of industrialisation and economic growth.

5. Data and methods

5.1. Data definitions and sources

We constructed our own dataset of sectoral shares for the period 1950–2005 as follows. The World Bank World Development Indicators (WDI) contains information about the value added shares at current prices of major sectors: agriculture, industry, manufacturing and services. These data originally derive from the UN national accounts database, but still have many gaps. For most developing countries, the data are only available from 1966 onwards. We complemented the WDI data set with data from the early UN national accounts statistics (paper publications) for the early years and the missing years, and also used other sources to fill gaps in the database (such as the Groningen Growth and Development Centre 60-industry, 10-industry and EUKLEMS databases[2], the UNIDO Industrial Statistics database, and, incidentally, country sources). The manufacturing data are described in detail in Szirmai (2012) and the references there. The sectoral breakdown is very aggregate and more detailed breakdown would be preferable. However, there is a clear trade-off between the coverage of the sample in time and space and the degree of breakdown. In this paper, we opted for maximising sample size for a long period.

For per capita growth we used the Maddison (2009) dataset of historical GDP statistics as our basic source of data. For human capital, one of our control variables, we used the Barro and Lee (2010) dataset for average years of education for the population of above fifteen years of age. We filled in a few gaps in these data using Lutz et al. (2007), Cohen and Soto (2007) and Nehru et al. (1995). Additional control variables were population size, an index of openness and climate zone. The index of openness (exports plus

[2] Groningen Growth and Development Centre (2009b, c): http://www.rug.nl/research/ggdc/databases.

imports in local as percentage of GDP) was taken from the Penn World Tables (version 6.3, openness defined in current prices), supplemented by data from the World Tables. Climate zone was measured as the percentage of land area in a temperate climate zone, based on data from Gallup et al. (1999). Because this variable has a very bimodal distribution, with peaks near 0 and 100, we transformed it to a binary variable that is 1 for countries with >50% of their land area in the temperate climate zone. Population data were derived from United Nations (2009), Taiwan from Maddison (2009), West Germany from the GGDC Total Economy Database (2009a).

5.2. Methods

We estimate panel regression models. Our main dependent variable is growth of GDP per capita per five year period (GR). The explanatory variables are the shares of manufacturing (MAN), and services (SER) in GDP at the beginning of each five year period. GDP per capita relative to the US (RELUS) at the beginning of each five year period represents the distance to the global productivity leader (a low value of RELUS implies a large gap), i.e., the stage of development of the country. Human capital (EDU) at the beginning of each five year period is our measure of absorptive capacity. Other variables include log population size (LNPOP), climate zone (KGATEMP, which is the dummy for whether a country lies in the temperate climate zone), the degree of openness (OPEN), and time-intercept dummies for each of the eleven five year time periods between 1950 and 2005. This yields the following model:

$$\begin{aligned}\mathrm{GR}_{t,t+5} = {} & \alpha\mathrm{MAN}_t + \beta\mathrm{RELUS}_t + \gamma\mathrm{EDU}_t \\ & + \mu\mathrm{LNPOP}_t + \kappa\mathrm{KGATEMP}_t + \lambda\mathrm{OPEN}_t + \delta D_{t,t+5},\end{aligned} \quad (1)$$

where $\mathrm{GR}_{t,t+5} = (1/5)(Y_{t+5} - Y_t)/Y_t$ and $D_{t,t+5}$ is a dummy variable for the time period $t - t + 5$. The Greek symbols are parameters that we will estimate later.

Because our data are a panel, we can account for unobserved country characteristics by including either fixed or random effects in the model, and do not have to rely only on OLS. It is important to do so, because it is conceivable that both growth rates and changes in manufacturing shares could be caused by some underlying factor. Table 1 summarises our data in terms of the means and standard deviations[3]. The standard deviation is broken down into the two dimensions of the panel, i.e., between countries ("between") and over time, within countries ("within"). As the table shows, the within component of our dependent variable (the growth rate of GDP per capita) is fairly large (larger than the mean, and almost twice as large as the between component). This means that this variable is especially volatile over time, within a single country, rather than between countries.

This pattern is exactly the opposite for the explanatory variables. For all of them, the between standard deviation is larger than its within counterpart. This means that the explanatory variables are relatively more volatile between countries than they are over time (within countries). These particular characteristics of the dependent and independent variables imply that we cannot rely purely on fixed effect estimations. These estimations eliminate the between effects completely, by expressing the data as deviations from the country means. Given the slow-changing nature of our explanatory variables, we would expect these between effects to be relatively strong, and hence we would like to include them in the estimations. Random effects estimations will do so, because they include both a within and a between element.

However, random effects estimations require that the country specific effect is independent of the explanatory variables. A Hausman test (of random vs. fixed effects) rejects the plain random effects model for our data. However, rather than resorting to fixed effects estimations only (which is often the implied "remedy"), we will use the Hausman and Taylor (1981) estimation method. This is essentially a random effects method that takes the dependency between the country effect and some of the dependent variables into account by using instrumental variables for the affected explanatory variables (i.e., the "endogenous" variables). The method requires that at least one of the instruments is time-invariant.

The Hausman–Taylor estimations also require us to determine which of the explanatory variables are endogenous, i.e., correlated with the country effect. To do this, we follow a procedure inspired by Baltagi et al. (2003) and also applied in Jacob and Osang (2007). In this procedure, we run a regression with our dependent variable growth and, one at a time, a single explanatory variable. Both a random effects and a fixed effects estimation is done, and a Hausman test is carried out to test whether the random effects estimation is appropriate. If it is, the variable is considered as exogenous (i.e., not correlated with the country effect). If the Hausman test indicates that the random effects estimation is not appropriate, we consider the variable as endogenous in the Hausman–Taylor estimations. In this way, openness and country size are shown to be exogenous. The climate zone variable is taken as the time-invariant exogenous variable without any testing (i.e., we assume rather than test that geography is exogenous).

6. Results

6.1. The "Simple Story": The effect of manufacturing on growth

We start by estimating the model of Eq. (1) on the complete sample (790 observations, 88 countries) and present the basic random effects (RE), fixed effects (FE), Hausman Taylor (HT) and between (BE) specifications below in Table 2. We present all estimation methods to illustrate that, given the nature of the data (between vs. within variance), the choice for a particular estimation method has

[3] The total number of countries in Table 1 is 92. This number includes three countries with border changes: pre-partition and post-partition Pakistan, pre-partition and post-partition Ethiopia and West Germany and reunited Germany. Due to missing data, four countries drop out of the dataset and the number of observations reduces to 922. Thus the regressions are run with a dataset of 88 countries and 922 observations.

Table 1
Descriptive statistics of the panel dataset, 1950–2050.

Variable	Description	Mean	Standard deviation			Observations		
			Overall	Within	Between	No. of obs.	No. of countries	T-bar
GR	Growth of GDP per capita	2.2	3.1	2.8	1.4	954	92	10.4
MAN	Share of manufacturing in GDP	17.8	8.3	4.5	7.2	833	92	9.1
SER	Share of services in GDP	49.4	12.0	7.4	10.2	836	92	9.1
RELUS	Per capita GDP relative to the USA	0.30	0.27	0.07	0.26	957	92	10.4
EDU	Education	5.2	2.9	1.5	2.5	922	88	10.5
KGATEMP	Dummy for temperate climate zone	0.28	0.45	0	0.45	1012	92	11.0
OPEN	Openness	64.1	42.9	20.5	37.5	946	92	10.3
LNPOP	Log of population	9.2	1.7	0.4	1.7	1003	92	10.9

Note: T-bar indicates the average number of observations per country.

strong implications. The between specification estimates the model in a pure cross-country way by using averages over time of all variables (within each country). This is the only model that we employ that does not contain any country-specific effects, and we include it only for comparison with the other models.

The Hausman test rejects plain random effects as an appropriate model (*p*-value of the test is 0.024). Therefore we consider the Hausman–Taylor estimations more appropriate than the random effects estimation. The share of manufacturing in GDP (MAN) is significant in three of the four specifications. The fixed effects estimation is non-significant, which is in line with our earlier worries about the limited within-variability of our explanatory variables (although the fixed effects estimator does provide a higher coefficient than either the random effects or the Hausman–Taylor estimator). The between estimation yields a coefficient for manufacturing that is about as large as the fixed effect model, but significant. It thus seems that our choice for Hausman–Taylor as the main estimator for subsequent estimations is a conservative one. Like the fixed effects estimation, the Hausman–Taylor estimation provides high values for rho (the share of country effects in unexplained variance), while rho is much lower for the random effects estimator. Because the fixed effects estimator does not put any restrictions on the fixed effects, the high value for rho adds further confidence in the Hausman–Taylor estimation, because it produces country effects that are as important as in the fixed effects model.

The share of services in GDP (SER) is never significant, which suggests at first sight that the service sector does not work as an engine of growth in our sample of

Table 2
Determinants of growth: the basic model 1950–2005.

Variable	Random effects			Fixed effects			Hausman–Taylor			Between		
	Coef	SE	Sig	Coef	SE	Sig	Coef	SE	Sig	Coef	SE	Sig
MAN#	0.045	0.018	**	0.065	0.039		0.045	0.021	**	0.063	0.030	**
SER#	0.020	0.020		0.017	0.026		0.022	0.016		−0.005	0.020	
RELUS#	−4.326	0.827	***	−9.123	2.168	***	−7.181	1.296	***	−4.011	1.000	***
EDU#	0.224	0.079	***	−0.184	0.244		−0.220	0.159		0.338	0.106	***
KGATEMP	1.526	0.349	***	(Dropped)			4.073	1.353	***	1.183	0.420	***
OPEN	0.010	0.006		0.008	0.009		0.008	0.005		0.014	0.005	***
LNPOP	0.220	0.136		−2.420	0.914	**	−0.372	0.297		0.316	0.123	**
D55–60	−0.950	0.365	***	−0.546	0.331		−0.740	0.401	*	−8.391	7.210	
D60–65	−0.089	0.374		0.893	0.448	**	0.442	0.407		−28.313	7.535	***
D65–70	−0.017	0.382		1.333	0.493	***	0.699	0.428		15.939	7.582	**
D70–75	−0.459	0.461		1.495	0.675	**	0.615	0.491		−19.690	5.570	***
D75–80	−0.912	0.499	*	1.564	0.773	**	0.475	0.532		3.440	7.028	
D80–85	−3.320	0.483	***	−0.355	0.830		−1.636	0.597	***	−11.577	5.831	*
D85–90	−2.418	0.506	***	0.933	0.940		−0.519	0.670		−1.728	4.899	
D90–95	−2.391	0.541	***	1.418	1.091		−0.207	0.737		−6.333	4.457	
D95–00	−2.470	0.642	***	1.907	1.288		0.043	0.821		−5.661	6.067	
D00–05	−2.280	0.682	***	2.456	1.375	*	0.455	0.890		−10.137	6.312	
Constant	−1.020	1.693		25.101	7.775	***	5.463	2.887	*	3.221	4.266	
Rho	0.126			0.837			0.831					
No. of obs	790			790			790			88		
No. of countries	88			88			88			88		
R^2 within	0.14			0.18								
R^2 between	0.28			0.02						0.51		
R^2 overall	0.19			0.00								

Standard errors for random effects and fixed effects are robust (adjusted for clusters).
* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.
Variables indicated with a # are treated as endogenous in the Hausman–Taylor estimation.

countries. Education (EDU) is significant in the between and random effects, and not in the fixed effects and the Hausman–Taylor. The coefficient on our catch-up term (country GDP per capita as a percentage of US GDP per capita, RELUS) is negative and significant in all models. The negative coefficient indicates that countries with a larger gap relative to the USA are growing more rapidly than countries closer to the USA. This is consistent with the convergence effects that are usually found in growth estimations, and which are either related to conditional convergence to a steady state, or to catching-up based growth related to the international diffusion of knowledge (see Fagerberg, 1994). KGATEMP is significant with a positive sign in all estimations, except in fixed effects (where it had to be dropped because it is time-invariant). Countries in the temperate climate zone tend to grow more rapidly than other countries (i.e., mostly, countries in the tropics and subtropics).

These initial results in Table 2 are in line with the engine of growth hypothesis. In the (conservative) Hausman Taylor specification, a 10 percent-point increase in the share of manufacturing raises growth by about 0.5 percent-point. Although this effect of manufacturing on growth is far from negligible, the size does not correspond to the effect that one would associate with an industrialisation-based growth spurt in some newly industrializing countries, for example in South-East Asia (Fagerberg and Verspagen, 1999). This is not surprising, since our model points to a linear relationship between the share of manufacturing and the growth rate, i.e., an increase of manufacturing from a low base-level has the same effect on the growth rate as an increase in manufacturing in a highly industrialised economy. In order to be able to capture the effect of industrialisation on development in a broader way, we will have to change the model.

Our preferred way of doing so is by adding interaction effects between the manufacturing variable (MAN) and some of the other explanatory variables in the model, in particular with RELUS and with EDU. An alternative way would be to include squared terms of the MAN and SER variables. However, as will be discussed below, we feel that many of the non-linearities result from specific phenomena (such as absorptive capacity and the role of knowledge-transfer in catching-up based growth) that are better modelled using interaction effects between the variables in our model.

6.2. Adding interaction terms to the base model

The new interaction variables that we introduce in the model are MANREL and MANEDU. MANREL is equal to MAN times RELUS, and MANEDU is MAN times EDU. We leave the original variables (MAN, EDU and RELUS) in the model as well. Because the variables that go into the interaction variables were considered as endogenous before, we also consider the interaction variables as endogenous in the Hausman–Taylor estimations.

The theoretical rationale for including the two interactions terms lies in the so-called technology-gap argument about economic growth (for example Abramovitz, 1986; Fagerberg, 1994; Verspagen, 1991). This literature argues that non-developed countries have a high growth potential because they may apply a large amount of knowledge from advanced countries in their productive systems. However, rather than knowledge transfer being an automatic process, the technology gap literature argues that the absorption of foreign knowledge are necessary requires investments for absorptive capability. Important parts of absorptive capability are education, infrastructure, the finance system, and so forth. Absorption also depends on the "right" sectors being developed in the economy, in terms of the knowledge that is available for transfer. This is what Abramovitz (1986) calls "congruence[4]".

The MANREL variable captures the basic idea of that the potential of a technology gap is largest at low levels of development (RELUS), and that it is realised primarily in the manufacturing sector (MAN), because that is where most knowledge is available abroad. The MANREL variable thus accommodates the notion that growth tends to be more rapid when countries have larger shares of manufacturing at lower levels of development. If the impact of manufacturing is larger in developing countries than in developed countries (as the theory argues), we expect that the sign of the coefficient on MANREL will be negative, and the coefficient on MAN will be positive.

The interaction between MAN and EDU is intended to capture the effect of absorptive capability (Verspagen, 1991; Cohen and Levinthal, 1989). Catching-up based growth through industrialisation is a process that involves knowledge transfer and innovation, and the efficiency with which this can take place depends on absorptive capability on the side of the knowledge "receiver". Although other factors than just education, such as infrastructure or political stability are involved (Abramovitz, 1986), we will proxy absorptive capability with EDU. The hypothesis is that a better educated workforce will make the marginal effect of manufacturing on growth higher. Hence our expectation is that the sign of the coefficient on the interaction effect of MANEDU is positive.

The two interaction effects lead to a new model[5] that can be represented by the following equation, where, for simplicity, we write υX instead of μLNPOP + κKGATEMP + λOPEN + δD_t and omit time subscripts[6]:

$$GR = \alpha MAN + \beta RELUS + \gamma EDU + \phi MANREL + \varphi MANEDU + \upsilon X, \quad (2)$$

where α, β, γ, ϕ, φ and υ are parameters that we estimate in the regression model.

Focusing on MANREL, we start by looking at the case where $\varphi = 0$. Then, the marginal effect of MAN on growth, i.e., the effect on growth of a 1-unit (percent-point) increase

[4] Catch up theory á la Abramovitz is much broader than can be captured by our variables. We make no attempt to operationalise his theories. However the theory does provide a rationale for interpreting human capital as a measure of absorptive capacity in the econometric exercises.

[5] We also experimented with other interactions. E.g., between size (LNPOP) and openness (OPEN). These interactions where not robustly significant, and did not affect the qualitative conclusions from the estimations.

[6] That is, X is a vector of variables LNPOP, KGATEMP, OPEN and D, and υ is the associated parameter vector.

of MAN is equal to $\alpha + \phi$RELUS (keep in mind that MANREL = MAN × RELUS). If $\phi < 0$ and $\alpha > 0$, countries with low values of RELUS (i.e., developing countries) will have a relatively high and (depending on the exact parameter values) positive marginal effect. At RELUS = $-\alpha/\phi$, the marginal effect is exactly zero[7]. For values of RELUS > $-\alpha/\phi$, the marginal effect of MAN on GR becomes negative. Thus, our "technology gap" hypothesis that accounts for the effect of industrialisation in catching-up growth in developing countries is that $\phi < 0$ and $\alpha > 0$.

Note that the interaction effect MANREL also provides a different view on the convergence effect that plays such a prominent role in the empirical growth literature (for example, Barro and Sala-i-Martin, 1995). From this point of view, the marginal effect of RELUS on growth is equal to $\beta + \phi$MAN. Convergence or catching-up means that this overall marginal effect is negative, for which it is sufficient (although not necessary) that $\beta, \phi < 0$. Then, an increase in MAN makes this effect even smaller ("more" negative), i.e., industrialisation reinforces the convergence or catching-up effect. In addition to the parameter expectations on α and ϕ that we have already presented, we therefore expect $\beta < 0$.

Now we turn to MANEDU and for simplicity momentarily set $\phi = 0$. Then, the marginal effect of MAN on GR is equal to $\alpha + \varphi$EDU. Keeping the earlier expectation of $\alpha > 0$ (i.e., a positive basic effect of manufacturing on growth), the additional expectation that $\varphi > 0$ is associated with the idea that absorptive capacity matters for growth. Then we may also note that the marginal effect of EDU on growth is equal to $\gamma + \varphi$MAN. It seems to be a reasonable hypothesis that this effect is always positive, which suggests, in addition to $\varphi > 0$, which we have already hypothesised, that $\gamma > 0$.

We will exclusively use the Hausman–Taylor specification as the estimation method for these more elaborate model specifications. The results for the model with interaction effects are documented in Table 3. Note that a similar model with interaction effects on SER instead of MAN yields no significant effect of SER on growth, which is why we do not document the detailed results (available on request). We also do not document results for a model in which OPEN was used as an additional interaction variable with MAN (available on request), because this interaction term was never significant.

The first column in Table 3 reproduces the base model of Table 2, i.e., a model without interaction effects. The second column in Table 3 includes only the interaction term MANREL, the third column includes both MANREL and MANEDU. When the interaction terms are included in the model, they are always significant. This justifies, in a statistical sense, their presence in the model. Moreover, the sign on the interaction effects is as expected (negative for MANREL and positive for MANEDU). In column 2, i.e., with only MANREL present, the signs on MAN and RELUS are also as expected, and significant. In the last column, MAN on its own is not significant and has a negative sign, but EDU and RELUS are. Here, EDU has a negative sign and is significant, which is against our expectations.

In order to obtain a full picture of the impact of these variables (EDU and RELUS) on growth, we look at the full marginal effects, i.e., including both the interaction and the direct effects. We therefore provide a visualisation of the marginal effects of RELUS and EDU in Figs. 1 and 2. These marginal effects depend on MAN, which is why this variable is on the horizontal axis of the figures. The solid line indicates the marginal effect itself; the dashed lines indicate the 95% confidence interval around this marginal effect. This confidence interval has been calculated on the basis of a *z*-test statistic that results from the variance-covariance matrix of the coefficients that are estimated in the regression, as well as the particular value of MAN on the horizontal axis (in the calculation of the confidence interval, this value of MAN is considered as non-stochastic). We use the last column in Table 3 to calculate these results (the graph for the marginal effect of RELUS does not differ substantially if we use the results in the second column).

The marginal effect of RELUS on growth is always negative (as expected), and significant, i.e., irrespective of the value of the manufacturing variable. This indicates that there is always a catching-up bonus, no matter whether the country is industrialised or not. However, this bonus does increase with the degree of manufacturing. For every 10% points industrialisation, the catch-up bonus increases by about 2.5% points (the exact slope of the line is −0.24).

As expected, the marginal effect of EDU on growth increases with industrialisation. However, this effect is mostly insignificant, i.e., most of the time the confidence interval around the solid line embraces the horizontal axis (zero marginal effect). At low values of manufacturing, the marginal effect of education is even negative, and significant. This is inconsistent with our expectations. To be precise, the marginal effect of 1 year of schooling (EDU) on growth is negative (positive) for values of MAN that are smaller (larger) than 24% (where the solid line crosses the horizontal axis). The marginal effect of EDU becomes significantly negative at values of MAN that are lower than about 12%. With the particular distribution of the MAN variable, this implies that about 27% of all observations show a significantly negative marginal effect of EDU. This picture of the impact of education on development may be hard to accept, but must be seen in light of the fact that we have found very little effect of EDU on growth in any regression so far. In Table 3, for example, the fixed effects and Hausman–Taylor estimations yielded negative and non-significant effects of EDU on growth. We must therefore accept that our regressions have little to say about the direct impact of human capital on growth. This not an uncommon finding in the literature (e.g., Pritchett, 2001; Krueger and Lindahl, 2001). It does not detract, however, on the role of human capital in our model as a factor in absorptive capability, which only depends on the coefficient on MANEDU, and this is significant and positive as expected.

The last marginal effect that we need to consider from Table 3 is that of MAN itself. This marginal effect depends

[7] Note that with $\phi < 0$ and $\alpha > 0$, $-\alpha/\phi$ is a positive number, and if the absolute value of ϕ > the absolute value of α, this number is also <1.

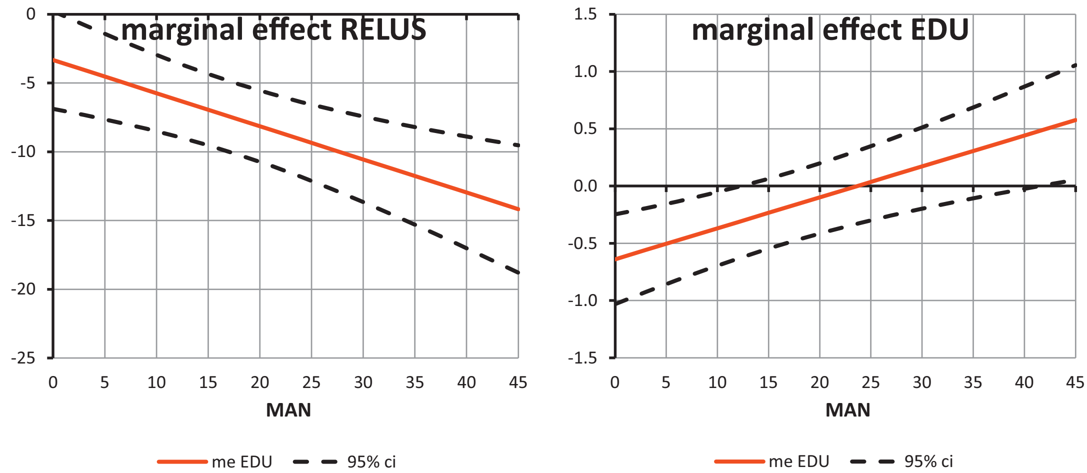

Fig. 1. The marginal effect of RELUS and EDU on GR (based on estimations in column 3 of Table 4).

Table 3
Determinants of growth: estimation results with interaction terms, Hausman Taylor specification.

	Base model without Interaction terms			Model with Interaction term MANREL			Model with interaction terms MANREL and MANEDU		
	(1)			(2)			(3)		
Variable	Coef	SE	Sig	Coef	SE	Sig	Coef	SE	
Endogenous									
MAN	0.045	0.021	**	0.087	0.031	***	−0.020	0.043	
SER	0.022	0.016		0.018	0.016		0.012	0.016	
RELUS	−7.181	1.296	***	−4.824	1.803	***	−3.330	1.813	*
EDU	−0.220	0.159		−0.202	0.158		−0.639	0.199	***
MANREL				−0.118	0.064	*	−0.241	0.072	***
MANEDU							0.027	0.007	***
Exogenous									
OPEN	0.008	0.005		0.007	0.005		0.005	0.005	
LNPOP	−0.372	0.297		−0.312	0.288		−0.070	0.236	
	−0.740	0.401	*	−0.730	0.401	*	−0.757	0.401	*
	0.442	0.407		0.433	0.406		0.428	0.404	
D55–60	0.699	0.428		0.673	0.427		0.655	0.422	
D60–65	0.615	0.491		0.544	0.490		0.545	0.483	
D65–70	0.475	0.532		0.358	0.531		0.330	0.520	
D70–75	−1.636	0.597	***	−1.782	0.597	***	−1.811	0.582	***
D75–80	−0.519	0.670		−0.684	0.669		−0.743	0.649	
D80–85	−0.207	0.737		−0.399	0.736		−0.432	0.714	
D85–90	0.043	0.821		−0.153	0.820		−0.135	0.795	
D90–95	0.455	0.890		0.254	0.887		0.283	0.861	
D95–00	0.008	0.005		0.007	0.005		0.005	0.005	
D00–05	−0.372	0.297		−0.312	0.288		−0.070	0.236	
Time invariant									
KGATEMP	4.073	1.353	***	4.057	1.306	***	4.566	1.096	***
Constant	5.463	2.887	*	4.557	2.815		4.374	2.416	*
Rho	0.831			0.817			0.720		
No. of obs	790			790			790		
No. of countries	88			88			88		

* $p<0.1$.
** $p<0.05$.
*** $p<0.01$.

on RELUS and EDU. We choose to visualise this effect by constructing a RELUS–EDU flat plane, and dividing this plane into two parts, of which one corresponds to a positive marginal effect of MAN (on growth), and the other to a negative marginal effect of MAN. This is done in Fig. 2. The solid line divides the RELUS–EDU plane into the two parts[8]. Above this line, the marginal effect of MAN is positive, below the line, the marginal effect is negative. The dashed lines again represent the 95% confidence

[8] To be precise, the solid line in Fig. 2 is described by the equation $EDU = -(\alpha + \phi\ RELUS)/\varphi$.

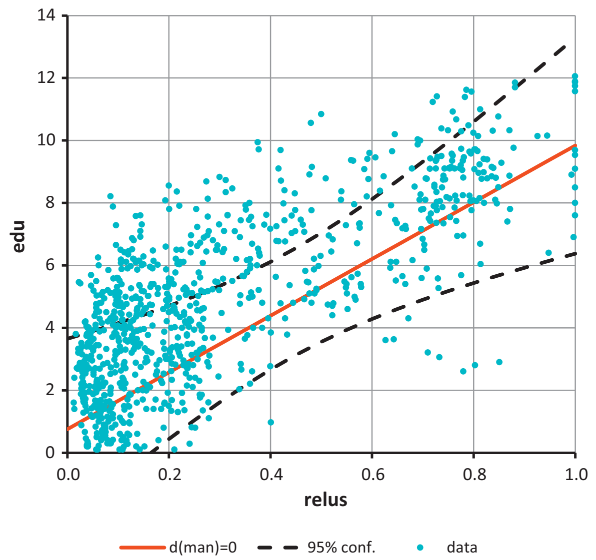

Fig. 2. The marginal effect of MAN on GR (based on estimations in column 3 of Table 4).

interval around the solid line. As before, EDU and RELUS are considered as non-stochastic variables, and the confidence interval is determined using a *z*-test based on the entire variance-covariance matrix of the estimation. The dots in the figure represent actual observations. Whenever an observation is above (below) the highest (lowest) dotted line, the observation represents a case where manufacturing contributed positively (negatively) to growth, according to our regressions.

The upward-sloping nature of the line in Fig. 2 implies that especially countries with low levels of development (i.e., high catching-up potential) and high human capital, will show a positive effect of manufacturing on growth. This is fully in line with our theoretical expectations. We see a fairly large number of observations above the highest dotted line, but also a large number of observations between the dotted lines (i.e., insignificant marginal effect of manufacturing). Only a small number of observations show a negative and significant marginal effect of manufacturing. Thus, the results in Fig. 2 generally support the engine of growth hypothesis in the "extended" form of Eq. (2).

Fig. 2 also sheds light on the interpretation of the negative (and significant) coefficient of MAN in the last column of Table 3. In itself, such a negative sign may appear to go against our theoretical expectations, because it indicates that, without considering the effect of RELUS and EDU, the effect of manufacturing on growth is negative. However, as the figure shows, this is "compensated" by even very modest values of EDU and catching-up potential. In other words, the negative coefficient of MAN does not point in any way to a negative marginal effect of manufacturing on growth, because the interaction terms "compensate".

It is also interesting to look at a number of individual countries, especially those that are prominent cases in the literature about industrialisation and development, and investigate where they fit in Fig. 1. In Asia, Korea and Taiwan, both famous cases that were part of the "Asian Miracle," were outside the confidence interval in Fig. 2 (i.e., had sufficiently high education levels given their development level to expect a positive effect of industrialisation on growth) for the entire period, i.e., since 1950. Hong Kong, another country that was part of the Asian Miracle, fell outside the confidence interval in 1970, but dropped into the confidence interval again in 1990 (by then it was so highly developed that the catching-up bonus for manufacturing became small). Japan started above the dotted line, but fell below it in 1970. The Philippines passed the dotted line in 1965, Malaysia in 1975, Indonesia in 1990 and India in 2000. China provides an interesting case. It fell within the confidence limits till 1970, but moved beyond the confidence period and remained there during its long period of accelerated growth since 1978.

In Latin America, we do not find any major countries that were already above the dotted line in 1950. Chile was the first to pass in 1965; other countries were later: Argentina in 1975, Colombia in 1980, Mexico in 1985, and Brazil in 1995. In Africa, countries generally take even longer to rise above the dotted line during our period of investigating. Ghana (1975), South Africa (1980), Botswana (1985), Kenya (1985), Egypt (1990), Tanzania (1990), Nigeria (1995), and Uganda (1995) are examples. Most European and other developed countries, although they have high levels of education, do not have significantly positive marginal effects of manufacturing. For these countries the share of manufacturing has become less important for growth, but this is related to their high level of development.

6.3. *Splitting up by time periods: Is the effect of manufacturing different in different periods*

We split the complete time span of 11 periods into 3 sub samples: 1950–1970, 1970–1990 and 1990–2005, and proceed by estimating the model with slope shift dummies for each of the periods to see whether the effects over manufacturing change over time[9]. The Hausman Taylor results are reproduced in Table 4.

On first sight, the effects of adding period slope shift dummies in column 1 are quite dramatic. While the coefficient of manufacturing was positive and significant in the base model in Table 3, it now becomes insignificant for 1950–1970 and 1990–2005. The share of services in the second period now also has a significant effect on growth, and the effect of education in the first period is significantly negative. It is also interesting to note that openness, which so far has not been significant, has a significant and positive sign in the last period. We also have a significant and negative sign for country size (LNPOP) in the first period.

However, we have seen in the previous section that the "extended" engine of growth hypothesis may be more realistic than the simple version. In other words, it is important to examine the interaction between manufacturing and other determinants of growth, so we proceed to add the interaction terms MANREL and MANEDU in columns 2 and

[9] Note that by applying slope-shift dummies, rather than estimating the model separately for each of the 3 periods, we assume that the country effect is fixed over the entire period 1950–2005.

Table 4
Estimations for three periods, 1950–1970, 1970–1990, 1990–2005.

	No interaction terms			With interaction term MANREL			With MANREL and MANEDU		
	(1)			(2)			(3)		
Variable	Coef	SE	Sig	Coef	SE	Sig	Coef	SE	
Endogenous									
MAN 50–70	−0.029	0.033		0.029	0.042		−0.082	0.052	
MAN 70–90	0.056	0.032	*	0.114	0.044	**	0.007	0.064	
MAN 90–05	0.035	0.032		0.110	0.045	**	−0.066	0.101	
SER 50–70	−0.001	0.022		−0.013	0.023		−0.005	0.023	
SER 70–90	0.104	0.024	***	0.098	0.024	***	0.098	0.024	***
SER 90–05	0.007	0.021		−0.003	0.021		−0.005	0.021	
RELUS 50–70	−5.381	1.498	***	−0.206	2.578		3.131	2.743	
RELUS 70–90	−12.39	1.656	***	−7.811	3.127	**	−4.869	3.473	
RELUS 90–05	−11.00	1.628	***	−6.376	2.900	**	−2.563	3.354	
EDU 50–70	−0.580	0.197	***	−0.560	0.197	***	−1.422	0.320	***
EDU 70–90	−0.234	0.178		−0.258	0.182		−0.713	0.305	**
EDU 90–05	−0.160	0.174		−0.114	0.175		−0.656	0.338	*
MANREL 50–70				−0.209	0.090	**	−0.428	0.110	***
MANREL 70–90				−0.200	0.114	*	−0.318	0.137	**
MANREL 90–05				−0.266	0.126	**	−0.441	0.169	***
MANEDU 50–70							0.048	0.014	***
MANEDU 70–90							0.024	0.013	*
MANEDU 90–05							0.030	0.018	*
Exogenous									
OPEN 50–70	0.008	0.007		0.010	0.007		0.009	0.007	
OPEN 70–90	0.003	0.007		0.002	0.007		0.000	0.006	
OPEN 90–05	0.013	0.006	**	0.009	0.006		0.007	0.006	
LNPOP 50–70	−0.716	0.381	*	−0.680	0.380	*	−0.434	0.347	
LNPOP 70–90	−0.619	0.376		−0.646	0.375	*	−0.345	0.343	
LNPOP 90–05	−0.494	0.366		−0.535	0.365		−0.257	0.336	
D65–70	−0.587	0.393		−0.553	0.392		−0.644	0.391	*
D70–75	0.779	0.406	*	0.811	0.406	**	0.700	0.403	*
D75–80	1.283	0.439	***	1.321	0.439	***	1.145	0.434	***
D80–85	−5.346	2.382	**	−4.591	2.418	*	−5.061	2.473	**
D85–90	−5.295	2.406	**	−4.585	2.442	*	−5.088	2.496	**
D90–95	−7.493	2.463	***	−6.799	2.497	***	−7.287	2.551	***
D95–00	−6.520	2.515	**	−5.811	2.546	**	−6.295	2.599	**
D00–05	−3.487	2.310		−2.716	2.333		−1.702	2.708	
Time invariant									
KGATEMP	5.660	1.679	***	5.706	1.676	***	5.714	1.489	***
Cons	10.871	3.720	***	9.810	3.730	***	9.248	3.451	
Rho	0.897			0.897			0.868		
No. of obs	790			790			790		
No. of countries	88			88			88		

* $p < 0.1$.
** $p < 0.05$.
*** $p < 0.01$.

3, again with slope dummies for all three periods. As before, all interactions terms that we add are significant, and have the expected sign (i.e., for all three subperiods). The positive impact of services in the second subperiod is robust to the inclusion of the manufacturing interaction effects, and so is the negative country size effect in the first subperiod (it is now also significant in the second subperiod). Openness is no longer significant in the regressions with manufacturing interaction effects.

We proceed to look at the marginal effects of manufacturing on growth for the three subperiods, based on column 3 of Table 4. In order to save space, we do not discuss the marginal effects of RELUS and EDU as in Fig. 1. Instead, in Fig. 3, we present a similar analysis as in Fig. 2, for all three subperiods of the estimations in Table 4. As expected on the basis of the regression results, the lines in Fig. 3 have the same basic (upward-sloping) shape as in Fig. 2. For each of the subperiods, we have a majority of observations that lie within the confidence interval, i.e., there is no significant effect of manufacturing on growth for these observations. However, there are also a substantial number of observations for which the marginal effect is positive, i.e., those that lie above the confidence interval. Only in the first subperiod do we find some observations that lie below the lower dashed line, i.e., those that have a negative effect of manufacturing on growth.

In terms of a comparison between the subperiods, it is noteworthy that in the last subperiod, i.e., after 1990, only countries with very low levels of GDP per capita (below RELUS = 0.2) seem to have a positive impact of manufacturing on growth. Before 1990, there were also a number of countries with RELUS between 0.2 and, say, 0.5, that had a

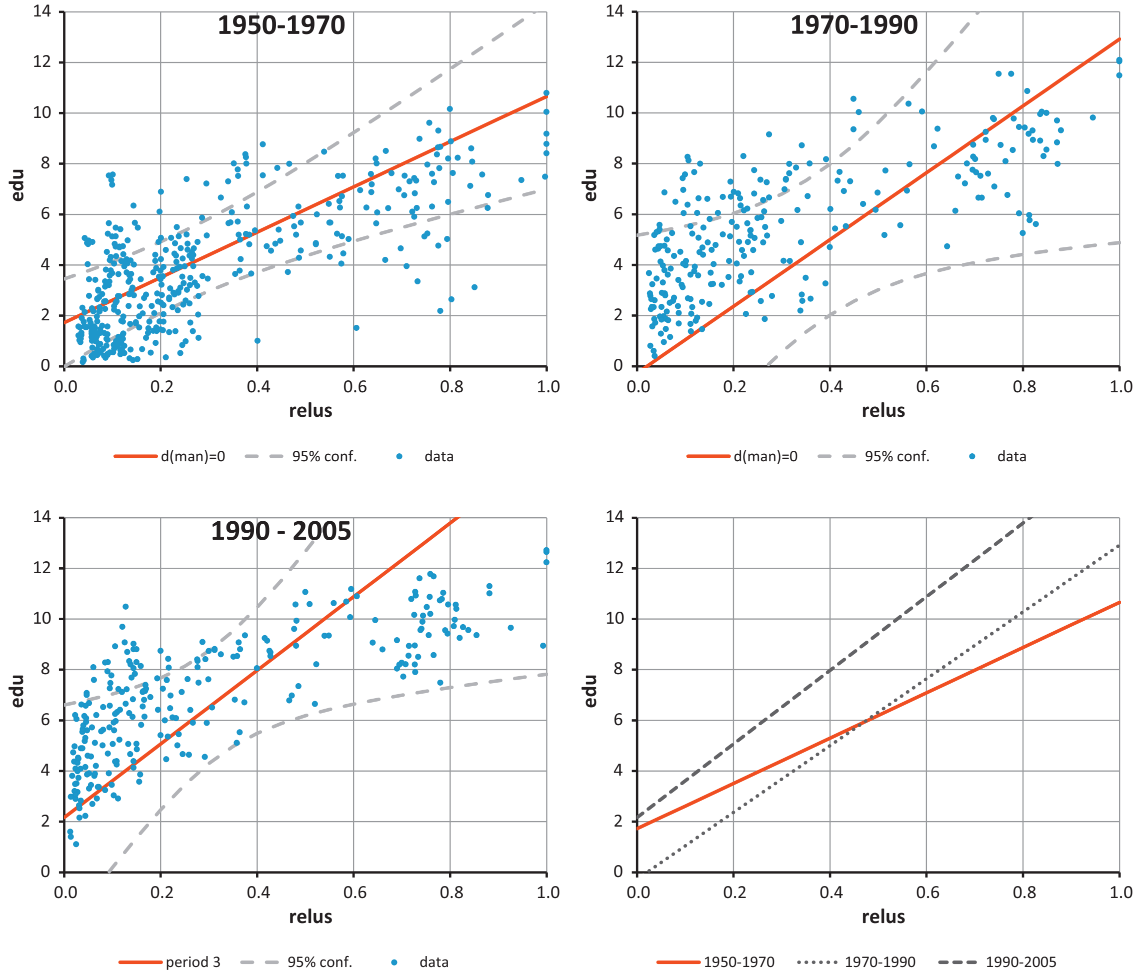

Fig. 3. Marginal effects of manufacturing, subperiods.

significant impact of manufacturing on growth. Obviously, this result is related to the position of the solid lines in the diagram, i.e., the joint effect of the estimated coefficients of MAN, MANEDU and MANREL in column 3 of Table 4.

The bottom-right quadrant of Fig. 3 summarises the curves in one diagram. This compares "how easy" manufacturing as a growth strategy was in the three subperiods (the more the curve shifts to the right-lower corner of the diagram, the "easier" it becomes to grow by industrializing). From 1950–1970 to 1970–1990, the change in the position is essentially a rotation (around the point RELUS = 0.5, EDU = 6) that "favours" the least developed countries. For RELUS < (>) 0.5, the education threshold for a positive marginal effect of manufacturing becomes slightly lower (higher). A somewhat more dramatic effect occurs in the period 1990–2005, when the curve shifts upward. This makes an industrialisation-based growth strategy "harder" than during the earlier subperiods[10]. As a result of this shift, the "middle-income" observations (RELUS between 0.5 and 0.2) now fall within the confidence interval, rather than outside, as before. It seems global conditions have changed in a way that especially affects these middle-income countries.

7. Summary and conclusions

In this paper we analysed a novel panel data set with information about the shares of manufacturing and services in GDP for a sample of 88 countries for the period 1950–2005. We regressed average five year growth rates on shares of manufacturing and services, and a set of control variables. The aim of the analysis was to test the hypothesis that manufacturing acted as an engine of growth, which would suggest that expanding the share of manufacturing in GDP is the key to more rapid growth and economic development.

[10] On first sight, it seems contradictory that the increasing difficulty of industrialisation-based growth coincides with the spectacular success of Chinese industrialisation. However, inspection of the scatterplots in Figs. 2 and 3 reveals that from 1978 onwards, China is located above and to the left of the upper confidence limits. It combines relatively low levels of comparative income with very high levels of human capital. It may well be that Chinese competition is one of the reasons why industrialisation in developing countries has become harder on average.

For the total sample, we find a moderate positive impact of manufacturing on growth in line with the engine of growth hypothesis. No such effects are found for services. Splitting our sample into the subperiods 1950–1970, 1970–1990 and 1990–2005 we only find a direct effect of manufacturing on growth for 1970–1990. Services also have a positive effect on growth during this period.

We also find interesting interaction effects of manufacturing with education and income gaps. The interaction between education and manufacturing has a positive and significant effect on growth in all periods, and the interaction between manufacturing and relative GDP per capita is negative, again for all subperiods. In other words, there is a positive effect of manufacturing on growth in developing countries with a highly educated workforce. These results based on the interaction effects support the extended version of our engine of growth hypothesis, which states that manufacturing is especially effective as a growth strategy at early phases of development, but also critically depends on absorption capability (in our case, human capital). A caveat should be entered with regard to causality. We do not test hypotheses about the various mechanisms identified in literature through which the manufacturing sector interacts with the wider economy. We are primarily interested in the question whether manufacturing in some way or other has a special role to play in growth. We do try to account for unobserved country effects by using fixed effects, random effects and Hausman Taylor specifications.

In a comparison of the subperiods, it seems that since 1990, manufacturing is becoming a somewhat more difficult route to growth than before. Ever greater amounts of human capital are required to achieve the same positive marginal effects of expanding the manufacturing sector, and the catching-up bonus seems to have become smaller. This has especially led to a number of countries at intermediate levels of development no longer benefitting from manufacturing as an engine of growth.

One future direction for our research is to expand the sample of countries. In particular, former centrally planned economies are now underrepresented. A second direction is to include shares of manufacturing in exports as explanatory variables, thus achieving a more satisfactory analysis of the role of openness (which in our results is hardly ever significant in explaining growth). A third direction is to focus on the relationships between growth rates of manufacturing and growth rates of the total economy. A fourth direction is to provide more sectoral detail, especially also within the services sector. In particular, we need to distinguish between market services and non-market services and within industry between mining, manufacturing, construction and utilities. Finally, in a subsequent analysis we would like to include policy variables and indicators of institutional characteristics in the analysis.

Acknowledgements

We thank Stephen Broadberry, Bart Los and two anonymous referees for valuable comments and criticisms.

References

Abramovitz, M., 1986. Catching up, forging ahead and falling behind. Journal of Economic History 46 (386), 406.

Baltagi, B., Brensson, G., Pirotte, A., 2003. Fixed effects random effects or Hausman–Taylor? A pretest estimator. Economics Letters 79 (3), 361–369.

Barro, R.J., Lee, J.-W., 2010. A New Data Set of Educational Attainment in the World, 1950–2010. NBER Working Paper No. 15902.

Barro, R.J., Sala-i-Martin, X., 1995. Economic Growth. McGraw-Hill, New York, NY.

Baumol, W.J., 1967. Macro-economics of unbalanced growth: the anatomy of urban crises. American Economic Review 57 (3), 415–426.

Chakravarty, S., Mitra, A., 2009. Is Industry still the engine of growth? An econometric study of the organized sector employment in India. Journal of Policy Modeling 31, 22–35.

Cohen, W.M., Levinthal, D.A., 1989. Innovation and learning: the two faces of R&D. Economic Journal vol. 99 (397), 569–596.

Cohen, D., Soto, M., 2007. Growth and human capital: good data, good results. Journal of Economic Growth 12, 51–76.

Cornwall, J., 1977. Modern Capitalism. It's Growth and Transformation. Martin's Press, New York, St.

Dasgupta, S., Singh, A., 2005. Will Services be the new engine of Indian economic growth? Development and Change 36 (6), 1035–1057.

Fagerberg, J., 1994. Technology and international differences in growth rates. Journal of Economic Literature 32, 1147–1175.

Fagerberg, J., Verspagen, B., 1999. Modern capitalism in the 1970s and 1980s. In: Setterfield, M (Ed.), Growth, Employment and Inflation. MacMillan, Houndmills, Basingstoke.

Fagerberg, J., Verspagen, B., 2002. Technology-gaps, innovation–diffusion and transformation: an evolutionary interpretation. Research Policy 31, 1291–1304.

Falvey, R.E., Gemmell, N., 1996. Are services income-elastic? Some new evidence. Review of Income and Wealth 42 (3), 257–269.

Fei, J.C.H., Ranis, G., 1964. Development of the Labour Surplus Economy. Theory and Policy. Irwin, Homewood, IL.

Gallup, J.L., Sachs, J.D., Mellinger, A.D., 1999. Geography and economic development. International Regional Science Review 22, 179–232.

Guerrieri, P., Meliciani, V., 2005. Technology and international competitiveness: the interdependence between manufacturing and producer services. Structural Change and Economic Dynamics 16, 489–502.

Gerschenkron, A., 1962. Economic Backwardness in Historical Perspective. Harvard University Press, Cambridge.

Groningen Growth and Development Centre/Conference Board (GGDC), 2009a. Total Economy Database. GGDC (downloaded 2009).

Groningen Growth and Development Centre (GGDC), 2009. EU KLEMS database. ⟨http://www.rug.nl/research/ggdc/data/eu-klems-database⟩ (downloaded 2009).

Groningen Growth and Development Centre (GGDC), 2009. Ten-sector database. ⟨http://www.rug.nl/research/ggdc/data/10-sector-database⟩ (downloaded 2009).

Hausman, J.A., Taylor, W.E., 1981. Panel data and unobservable individual effects. Econometrica 49 (6), 1377–1398.

Higgins, B., Higgins, J.D., 1979. Economic Development of a Small Planet. Norton and Co, New York, NY.

Hirschman, A.O., 1958. The Strategy of Economic Development. Westview Press, Boulder and London.

Inklaar, R., Timmer, M.P., van Ark, B., 2008. Market services productivity across Europe and the U.S. Economic Policy 23 (53), 139–194.

Iscan, T., 2010. How much can Engel's law and Baumol's disease explain the rise of service employment in the United States? The B.E. Journal of Macroeconomics 10 (1) (Article 26) http://www.degruyter.com/view/j/bejm.2010.10.1/bejm.2010.10.1.2001/bejm.2010.10.1.2001.xml?format=INT

Jacob, J., Osang, T., 2007. Institutions, Geography and Trade: A Panel Data Study. Departmental Working Papers 0706, Southern Methodist University, Department of Economics.

Jorgenson, D.W., Ho, M.S., Stiroh, K.J., 2005. Information Technology and the American Growth Resurgence. MIT Press, Cambridge, Massachusetts.

Kaldor, N., 1966. Causes of the Slow Rate of Growth of the United Kingdom. Cambridge University Press, Cambridge.

Kaldor, N., 1967. Strategic Factors in Economic Development. Cornell University Press, Ithaca, NY.

Katuria, V., Raj, R.S.N., 2009. Is manufacturing an engine of growth in India? Analysis in the post nineties. In: Paper for the UNU-WIDER/UNU-MERIT/UNIDO Workshop, Pathways to Industrialisation in the 21st Century. New Challenges and Emerging Paradigms, 22–23 October, 2009, Maastricht.

Kitching, G., 1982. Development and Underdevelopment in Historical Perspective. Methuen, London.
Krueger, A., Lindahl, M., 2001. Education for growth: why and for whom? Journal of Economic Literature XXXIX, 1101–1136.
Lutz, W., Goujon, A.S.K.C., Sanderson, W., 2007. Reconstruction of population by age, sex and level of educational attainment of 120 countries for 1970–2000. Vienna Yearbook of Population Research vol. 2007, 193–235.
Maddison, A., 2009. Historical Statistics, World Population, GDP and Per Capita GDP 1-2006 AD, ⟨http://www.ggdc.net/maddison/⟩ (Downloaded: July 2009).
Mahanolobis, P.C., 1953. Some observations on the process of growth of national income. Sankhya 12, 307–312.
Marks, D., 2009. Accounting for Services. The Economic Development of the Indonesian Service Sector, ca 1900–2000. Utrecht University, Aksant (Dissertation).
Nehru, V., Swanson, E., Dubey, A., 1995. A new database on human capital stock in developing and industrial countries: sources, methodology and results. Journal of Development Economics 46, 379–401.
Pacheco-López, P., Thirlwall, A.P., August, 2013. A new interpretation of Kaldor's First Growth Law for Open Developing Economies. In: University of Kent, School of Economics Discussion Papers, KDPE 1312.
Park, S.H., 2009. Linkages between industry and services and their implications for urban employment generation in developing countries. J. Dev. Econ. 30, 359–379.
Park, S.H., Chan, K., 1989. A cross-country input-output analysis of intersectoral relationships between manufacturing and services and their employment implications. World Dev. 17 (2), 199–212.
Pritchett, L., 2001. Where has all the education gone? World Bank Economic Review 15, 367–391.
Riddle, D.I., 1986. Service-Led Growth: The Role of the Service Sector in World Development. Praeger, New York, NY.
Rodrik, D., May, 2009. Growth after the Crisis. Harvard Kennedy School, Cambridge, MA.
Rowthorn, R., Coutts, K., 2004. De-industrialisation and the balance of payments in advanced economies. Cambridge Journal of Economics 28 (5), 767–790.
Rostow, W.W., 1960. The Stages of Economic Growth, Cambridge. Cambridge University Press, Cambridge.
Syrquin, M., 1984. Resource allocation and productivity growth'. In: Syrquin, M., Taylor, L., Westphal, L.E. (Eds.), Economic Structure and Performance—Essays in Honor of Hollis B. Chenery. Academic Press Inc, Orlando, FL, pp. 75–101.
Syrquin, M., 1988. Patterns of structural change. In: Chenery, H.B., Srinivasan, T.N. (Eds.), Handbook of Development Economics. North-Holland, Amsterdam, pp. 203–273.
Szirmai, A., 2012. Industrialisation as an engine of growth in developing countries 1950–2005. Structural Change and Economic Dynamics 23 (December (4)), 406–420.
Szirmai, A., 2015. Socio-Economic Development, second ed. Cambridge University Press, Cambridge.
Timmer, M.P., de Vries, G.J., 2009. Structural change and growth accelerations in Asia and Latin America: a new sectoral dataset. Cliometrica 3 (June (2)), 165–190.
Thomas, J.J., 2009. Why is Manufacturing Not the Engine of India's Economic Growth, Examining Trends, 1959–60 to 2008/9. Mimeo, New Delhi.
Triplett, J.E., Bosworth, B.P., 2006. 'Baumol's Disease' has been cured. IT and multifactor productivity in US services industry. In: Jansen, D.W. (Ed.), The New Economy and Beyond. Past, Present and Future. Elgar, Cheltenham (33 ff).
UNIDO, 2013. Industrial Development Report 2013 Sustaining Employment Growth: The Role of Manufacturing and Structural Change. UNIDO, Vienna.
United Nations, Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, 2009. World Population Prospects: The 2008 Revision. United Nations, ⟨http://esa.un.org/unpp⟩ (downloaded July 24, 2009).
Verspagen, B., 1991. A new empirical approach to catching up or falling behind. Structural Change and Economic Dynamics 2, 359–380.